Course Manual

Computer Systems Service Technician and
Network Administrator Associate Certificate
Programs

CITX1150

STRUCTURED CABLING SYSTEMS FOR COMPUTER NETWORKS
&
ADVANCED CABLING SYSTEMS

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Section 1 Overview of Networks

A: Rationale for standardization

If we want any two terminals to be able to communicate, regardless of the operating systems used, the machine language employed or the media used as the channel between the devices, we either have to force all the devices to use the same equipment, language etc., or create a standardized model. This model could then be used by all the vendors and software developers as a standard "canvas" on which future development could be pursued.

Prior to the development of the Structure Cabling System, every type of network had its own cabling requirements and topology. In order to change the network topology or to upgrade the system, a new cable structure had to be installed; a costly project once the building is built. Many older buildings still have the remains of the previous networks, existing as unused wiring in the ceilings and walls of the structure.

Many of the components of a commercial building have been standardized for years. The ac power outlets, plumbing, heating, ventilation and air conditioning, for example, have long been built to an acceptable standard. How often, for instance, do you need a power outlet and can not find one? Even the telephone company had a plan to adequately provide phone service to the current and future users of the office space.

In the 1970s and 80s, when computing cost went down and business started providing PC to the employees desk's, the need for a standard local network cabling system became obvious. The need to access mass storage devices, to communicate between users and to share expensive resources became a driving force behind the development of the Structured Cable System as we know it today.

One of the earliest Local Area Networks in use for business was the IBM Token Ring network, which required IBM cabling in a ring topology, special IBM connectors, and, of course, IBM terminals and network controllers. Aside from difficulties arising from the physical ring required (such as growth and scalability), the user was restricted to IBM equipment and software only. Although this was good for IBM, it was not good for the user, or for the other software developers or equipment manufacturers.

Wide Area Networks of the day tended to be point to point or multi-point tree structures. Again IBM with its' 3270 and System Network Architecture (SNA) networks tended to dominate the business world, at least in North America. Many companies combined a local token ring network, servicing branch offices, with a Point to Point network, accessing the main frame computer for the company. These networks tended to be unstable due to traffic patterns, bottlenecks and lack of redundant paths.

All this was before the Internet existed, and before the home computer market, and the public's interest in the Internet, took off.

A number of groups sought to develop a network model which would provide the software developers, the equipment manufacturers, and the physical medium companies a frame work of standard processes and interfaces. The ultimate aim was to allow a business to buy one vendor's software, run it on a second vendor's equipment, which was networked through a third vendor's carrier system.

The earliest example of such as model was developed by the Defence Advanced Research Projects Agency of the U.S. Department of Defence. Their aim was to create a robust, multi-path network which could join a number of different computer platforms, using different machine languages, access methods and speeds, into a resilient network capable of withstanding an armed attack. The Internet, as we know it now, is the direct result of the work done by Jon Postell and a multitude of other professional and amateur developers.

Unlike much software development today, DARPA used an open-source system of development, where literally anyone could suggest a method of achieving certain ends in a networking environment. Software developers could then work on the idea (if it seemed feasible) and either the ideas would pan out, and become a standard, or would fall by the wayside. A 4-layer model was used to separate the various tasks required to set-up, maintain and clear the network connection.

DARPA 4-Layer Network Model
Layer 4 **Host to Host Application Layer** (roughly equal to Layers 7, 6 &5 of the O.S.I. Model)
Layer 3 **Transport Layer** (Roughly equal to Layer 4 of the O.S.I. Model)
Layer 2 **Internetwork Layer** **Roughly** equal to Layer 3 of the O.S.I. Model)
Layer 1 **Local Network Layer** **(Roughly** equal to Layers 1 & 2 of the O.S.I. Model)

Figure 1-1 The DARPA 4-Layer Model

B: ISO Open Systems Interconnect Model

1 Purpose of the O.S.I. Model

The International Standards Organization (ISO), a branch of the United Nations, has established a standardized model of communication between computers. It is loosely based on the DARPA model, but has 7 layers rather than 4. This permits a greater refinement in the functionality of each layer. Structured Cable Systems use the OSI model as it has a separate layer for the physical network.

2 Structure and Function

The OSI model has 7 layers, which defines the interfaces between the various functions. This ensures each layer can communicate with the layer above and below it. In general each layer in one computer communicates directly with the equivalent layer in the second computer. For example, when a session is set up between 2 computers the Session Layer (Layer 5) of each computer communicate with each other. Some of the functions of each layer are given below.

3 Function

These layers are implemented in different Protocol Stacks and hardware elements to different levels, with Users talking on the Application Layers at both ends, and routers, gateways, WAN and LAN components talking on varying layers during the course of the transmission.

An example may be two letter writers, speaking different languages, communicate to each other only by using a number of interpreters and message handling groups. Each group would have specific functions such as changing English to Spanish, checking the spelling, signing the document and passing to the next group. The next group might do verification on the message, and generate an error number for the message, address an envelope, and then mail it.

4 The O.S.I. Layers

Layers 1 and 2 are the physical aspects of the OSI Model

a) Physical Layer

The Physical Layer is composed of the cables, connectivity hardware and transmission media and electrical functional and mechanical interfaces. This layer is responsible for the translation the data from its software, digital form, into electrical or light pulses to send the message for a long distance. Active elements of this layer do not "read" any of the data stream, but only amplify or distribute the signal, and include devices such as repeaters, regenerators, and Hubs.

Layer 1 also deals with connectivity issues such as the physical interfaces between devices, and is concerned with hardware construction, pin assignments, and level & type of signalling to be used. Connectors include DB9, DB15 and DB25 fittings, BNC connectors for the various coax cable types used in LANs, Centronics, Winchester, and DIN type connectors. Terms such as RS232C or V.35 refer to pin assignments and voltage levels on the various physical interfaces

A whole range of Registered Jack (RJ) types exist, borrowing from telephone connectors and running on UTP (Unshielded Twisted Pair). RJ11 and RJ12 wired for USOC2 or USOC3 for phones, RJ31, RJ45, RJ48S, for various LAN implementations. Work area cords, between the PC and the UTP, are further modified to provide specific services such as T568A, 10BaseT, MMJ etc. The Physical Layer interfaces upward with the Media Access Control sub-layer of Data Link Layer. Drawings of the major outlet configurations are given in the Appendix.

Open System Interconnect Model

Layer 7 **Application Layer** Application Software (i.e. Excel, CAD), User application processes Management functions.
Layer 6 **Presentation Layer** User Logon Network Redirector, Encryption and de-encryption Data interpretation including format and code translation
Layer 5 **Session Layer** Network security Virtual sessions Checkpoints Administration and control of sessions when multi-tasking
Layer 4 **Transport Layer** Error recognition & recovery Transparent data transfer End to End control Multiplexing & mapping
Layer 3 **Network Layer** Fragmentation and re-assembly Routing and interpretation of network (logical) addresses Switching, segmenting, blocking Flow control
Layer 2 **Data Link Layer** Establish, maintain and release data links Error & flow control on the physical medium Logical Link Control (LLC) Media Access Control (MAC) Service primitives and handshaking
Layer 1 **Physical Layer** Physical link between computer and the network Hardware addresses. Electrical, mechanical & functional control of data circuits

Figure 1-2 The O.S.I. 7-Layer Model

b) Data Link Layer

The Data Link Layer serves two major functions, and can be divided into two sub layers, the Media Access Control (MAC) sub-layer, and the Logical Link Control (LLC) sub-layer.

The MAC sub-layer is required to convert the software data stream from the upper layers in the work station into an acceptable form for the network in use. This includes packaging the information into an acceptable protocol frame, such as Ethernet (IEEE802.3) or Token Ring (IEEE802.5), and the creation of an error-detection value such as the Frame Check Sequence (FCS). The FCS is transmitted along with the frame, to provide a method by which the receiving device can verify the received message was error-free.

The LLC sub-layer functions include addressing the frame to the correct hardware on the network. The MAC address, as used in Ethernet networks, is a unique 48 bit address which is burnt into the Network Interface Card (NIC). The LLC is also responsible for maintaining the Link, the connection between the two devices. The LLC can do this by the transfer of positive acknowledgements (ACK), which may mean "your message received correctly", or negative acknowledgements (NAK), "your message received in errored condition".

The LLC and MAC sub-layers have 4 control paths between them, called the Service Primitives, which operate in similar fashion to the modem handshake process. Both these sub-layers reside on the NIC board in every addressable piece of equipment on the network. Other Layer 2 equipment includes Layer 2 Switches, Multiple Service Access Units (MSAU) for Token networks, Wireless LAN transceivers, and Optical/Electrical converters for fiber optic media networks

Layer 2 interfaces downward to the Physical Layer, the actual network cable or transmission media, and upward to the computer via the Network Layer.

Layers 3 thru 5 are (loosely) the Network Operating System Layers

c) Network Layer

The first layer in computer RAM, this layer is responsible for translating logical addresses (user or computer name or the IP address) to the physical 48 bit MAC address by using "look up tables". It also determines the routing path the data is to use and any fragmentation, bundling or re-assemble the data requires. Fragmentation is the process of breaking a large amount of data; say a graphics file, into smaller packets for transmission on the network. Bundling refers to the grouping of multiple packets into a coherent form and in order.

d) Transport Layer

The 4^{th} Layer is responsible for error recognition and recovery of the received data. If the data was received with errors it is recognized here, and a recovery (retransmission of the same information) may be requested. An example of a protocol using this mechanism is Transmission Control Protocol (TCP). On the other hand, the information may not be important, and this layer could dump the message without advising the source. User Datagram Protocol (UDP) uses this mechanism.

e) Session Layer

This layer is responsible for name recognition, Network security and check point placing, and session establishment of a virtual connection. Name recognition is yet another address, this time the Internet address, which gives the Domain of the LAN, etc. The three addresses a single work station may have include the user name (e.g. WWW.Microsoft.Com), the Internet Address (e.g. 213.127.89.70) and the NIC address (e.g. 4D.23.A1.76.B3.14). Network security is provided during the session setup, by the exchange of passwords and other encrypted mechanisms

Checkpoint placing is the process of allowing executable portions of applications to start working before the whole application is loaded. E.g., the Windows 95 logo "Starting Win 95" comes up long before the full application is loaded. As the load proceeds, other parts of the application may start working. The sending computer "places" these checkpoints, and the receiving computer reads them, and runs the executable portions.

The Session Layer is also responsible for multi-tasking. Through the use of Source and Destination Port “well-known” port numbers, this layer can establish multiple sessions at the same time. An example could be running a Web-Browser and E-mail service while on the Internet. Any new e-mail messages could be received (or sent) while still keeping access to a particular web-page for reading.

Layers 6 & 7 are in the Local Operating System

f) Presentation Layer

The 6th Layer is responsible for Logon Security, data encryption, transmission coding, and redirection. Logon security provides access to the local computer functions, but is not related to network security. Encryption is the coding of data for transmission, which provides a certain level of security on the network as the user messages will not be sent in plain English. The Transmission code used may be either one of the ASCII codes, or EBCDIC coding. The transmission code determines the value of the bits used in a byte to represent letters, characters and control codes. The redirector is a part of the Network Operating System which determines if the users command requires network resources or local resources.

This layer gets it’s name from it’s function, which is to present the operating system to the user, which may take the form of a command line interface (such as DOS or Linux) or a graphic user interface (a GUI, such as Microsoft’s Windows).

g) Application Layer

The 7th Layer is the application seen on the screen, and includes games, word processors, spread sheets, graphics applications, etc. This layer is the direct interface upward with the user, and downward to the Presentation Layer.

C: Protocols

1) Rules for communication

A protocol is simply an accepted way of conducting an exchange of messages, which may or may not include user data. An easily understood example is the way Canada Postal Service (figure 1-3) wants us to address our letters. The address in the centre of the envelope is regarded as the Destination Address, and must include the postal code number, a city name, the street address and the recipient’s name. A similar set of address data is placed in the upper left hand corner of the envelope, representing the source address. Lastly a message validation, the stamp in our example, must be stuck to the upper right hand corner. Without all these things, in their correct location, the mail will not go through.

What if you are sending a cheque to pay a bill? There are firm protocols regarding writing a cheque. You write the payee’s name on one line, and write your signature on another line. You write out the amount of the cheque, both in words and in numbers, and a valid date. Further, the cheque has to have your name and address, the name of the bank it is written on, and your bank account number. To ensure the money is applied to your account most of also include the return stub for the bill. All of these protocols have to be completed correctly in order for the goal, which is making your bill payment, is successful.

Another example from everyday life is the protocol you use to greet your boss or your spouse. Do you shake hands with the boss and hug our spouse, or is it the other way around? What if the boss is the spouse? The correct protocol in this case could vary with conditions…are you at home or at work?

In telecommunications, protocols are used to request diagnostics, send files, and cut steel. Long messages can be fragmented, encoded, scrambled, all before it leaves the clients office. Once this data string gets to the far end, the reverse process has to happen, in the same manner and order as the process occurred. Protocols have been developed to govern exchanges of all manners, and at different Layers with the OSI Model. Any one message, even “Good Morning” has to be packetized and depacketized, framed and sequenced, dissembled and reassembled under the same protocol rules. Otherwise the communication becomes chaos.

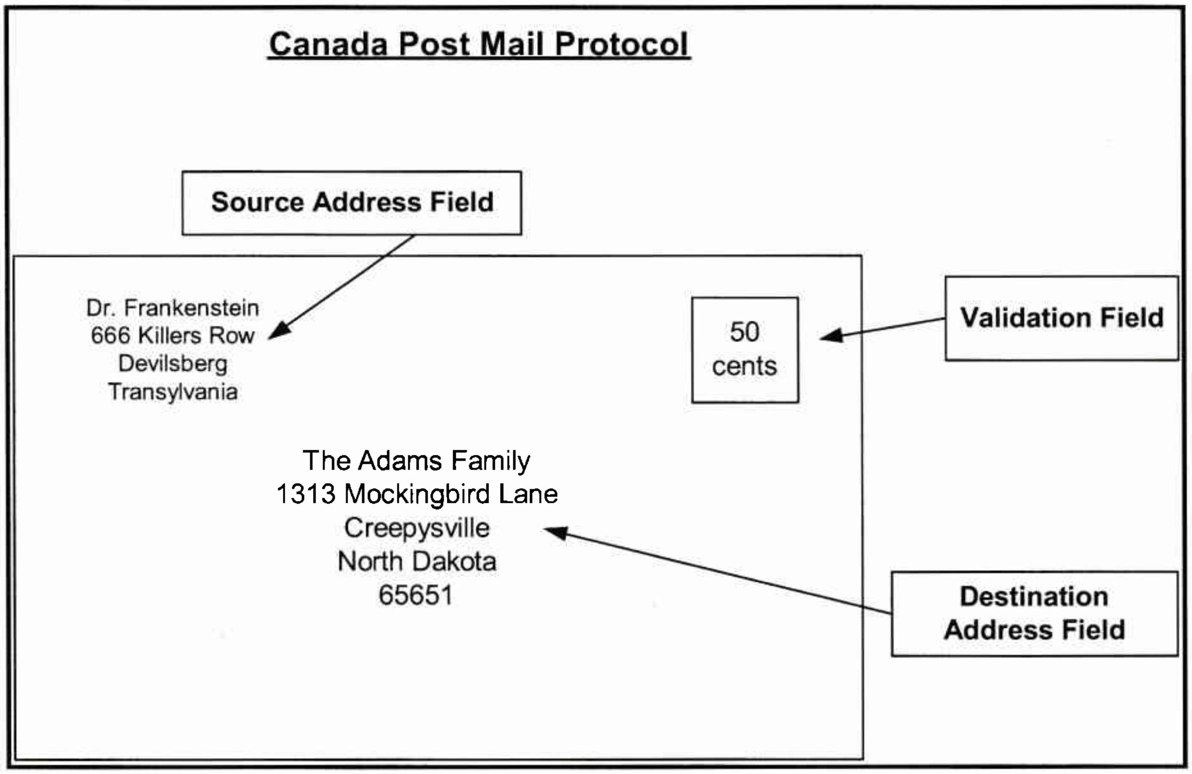


Figure 1- 3 Envelope Protocol for Canada Postal Service

A group of protocols maybe visualized as a stack of building blocks of various sizes and shapes, each one performing the functions required by the O.S.I. Layer they operate on, joining the one below and the one above in a smooth transaction. Further, these protocol suites and their various component protocols can be placed within the OSI Model layers as shown in Figure 1-4 on the next page.

2) <u>Protocol Enforcement</u>

A protocol is enforced on the network by the use of various Fields of information, with each field having a well defined location within the Protocol Header. For any particular protocol, the type of information in each field is known by both the source and destination equipment. A field may be of a fixed length (many are 8 bits or multiples of 8 bits in length), or it may be of variable length, such as a data field.

In the Canada Post protocol illustration, the envelope could be considered the Header, and the three groups of information would then be the Fields. The source and destination address fields are of variable length and makeup, while the validation field (the stamp) has a defined length. Try sending a letter with too short a stamp field (that is, a stamp of too small a value) and the letter gets returned.

Sample TCP/IP Suite built on an Ethernet

Layer								
7 Application Layer 6 Presentation Layer 5 Session Layer	File Transfer Protocol FTP RFC 959 Tfc 20 Ctrl 21	Simple Mail Transfer Protocol SMTP RFC 821 Port 25	TELNET Protocol RFC 854 Port 23	Dynamic Host Configuration Protocol DHCP RFC ?? Cl 68 Svr 67	Domain Name System DNS RFC 1035 Port 53	Simple Network Management Protocol SNMP RFC 1157 Msg 161 Traps 162		
4 Transport Layer	Transmission Control Protocol TCP RFC 793	User Datagram Protocol UDP RFC 768						
3 Network Layer	Address Resolution ARP RFC 826 RARP RFC 903	Internet Protocol IP RFC 791	Internet Control Message Protocol ICMP RFC 792	Routing Info Protocol RIP 1058	Open Shortest Path First OPSF RFC 1131			
2 Data Link Layer	Ethernet IEEE 802.3	Token Passing IEEE 802.5	Wireless IEEE 802.3g	Point to Point Protocols	SONET	Asynchronous Transfer Mode		
1 Physical Layer	100 ohm Unshielded Twisted Pair	Fiber Optics	Coaxial cable	Voice Grade Loops	Radio Frequency	Spread Spectrum	Infrared	

Notes:

1) Request For Comments (RFC) numbers indicated are current standard numbers
2) Well-known port address include Traffic (Tfc), Control (Ctrl), Client (Cl), Server (Svr), and Message (Msg) port numbers.
3) Location of the Protocols in the above Suite diagram does not imply their locations in any particular implementation of a Protocol Stack.

Figure 1- 4 Partial TCP/IP Suite with RFC Numbers

3) Encapsulation

When a message is meant for Network delivery, the user message must pass through the various layers of the source protocol stack so that the final data stream placed on the Physical Layer can be read, accepted and passed up the destination's protocol stack for ultimate presentation to the destination user.

As the message goes down the stack in the source equipment, each protocol used will add a header to the data, until Layer 2, which typically will add a header and a trailer. This process is called encapsulation, and the reverse process has to be performed by the destination equipment. There the destination's Layer 2 protocol reads the source's Layer 2 header and trailer, the destination's Layer 3 protocol reads the source's Layer 3 header, and so on. Each source Layer communicates its requirements to the equivalent destination Layer. The destination Layer then performs the function requested, such as "pass this message to your Web Browser" or "advise user of Ping status". Of course these messages are not in plain English, but are expressed as a bit code within some field of the header.

The specific information in each Header is determined by the requirements of the protocol in use, and the requirements of the O.S.I. Layer the particular protocol is operating on. Figure 1-5 shows an IEEE 802.3 (Ethernet) frame with 6 fields, such as addressing, length of the data being sent, and an error-checking number. Ethernet is a Layer 2 protocol commonly used in Local Area Networks (LANs), having a number of "flavours" including 10-Base-2, 10-Base-5, 10-Base-T, 100-Base-T and Gigabit networks. The upper layer data section may be anywhere from 46 to 1500 octets long, and contains the headers for the upper layer protocols and eventually the actual information being sent. Figure 1-6 shows the location of the Ethernet header in relation to the complete serial string of data in the full frame.

Preamble	Start Frame Delimiter	Destination Address	Source Address	Type	Layer 3 up headers and data	Frame Check Sequence
7 oct	1 oct	6 oct	6 oct	2 oct	46 to 1500 Oct	4 oct

Figure 1-5 Ethernet Header Construction used in Figure 1-6

Layer 2 →	Layer 3 →	Layer 4 →	Layers 5, 6 & 7 →		Layer 2
Ethernet Header	IP Header	TCP Header	FTP Header	User Data (Request for file)	FCS

Figure 1-6 The Encapsulated Frame Structure used in Figure 1-7

4) TCP/IPv4/IEE802.3 Protocol Stack

As an example of the way a number of protocols are used in the same message, let us look at a typical LAN implementation, using Ethernet (IEEE 802.3) on the Layer 2, TCP/IP as Layer 3 and 4 protocols, and File Transfer Protocol (FTP) as the upper layer (5, 6 and 7) protocol in use. This particular implementation owes its structure to the DARPA model, with FTP functioning on the Host-to-Host Application Layer (DARPA Layer 4, OSI Layers 7, 6 and 5). Figure 1-6 shows the encapsulated frame structure used by the protocol stacks shown in Figure 1-7.

FTP is a sample of a Client/Server relationship. The Client requests a service, in this case delivery of some file, which resides on a FTP Server computer. The operation requires 3 basic operations, namely the call set-up process, where the Client contacts the Server to set up a FTP session, a request for the transfer of a specific file, and the call clearing process.

The frame of information placed on the physical UTP network will consist of 4 headers, one for each protocol used in the stack. The Headers will perform the necessary functions of each Layer to ensure communication. For example, the Ethernet Header will contain the source and destination MAC addresses and the FCS (as a Trailer), the IP Header will contain the Logical (IP) address, the TCP Header will ensure error-free delivery to the Session Port address, and FTP Headers will establish confirm the Source may access the Server, the file the Server has to look for, and other Client/Server functions required.

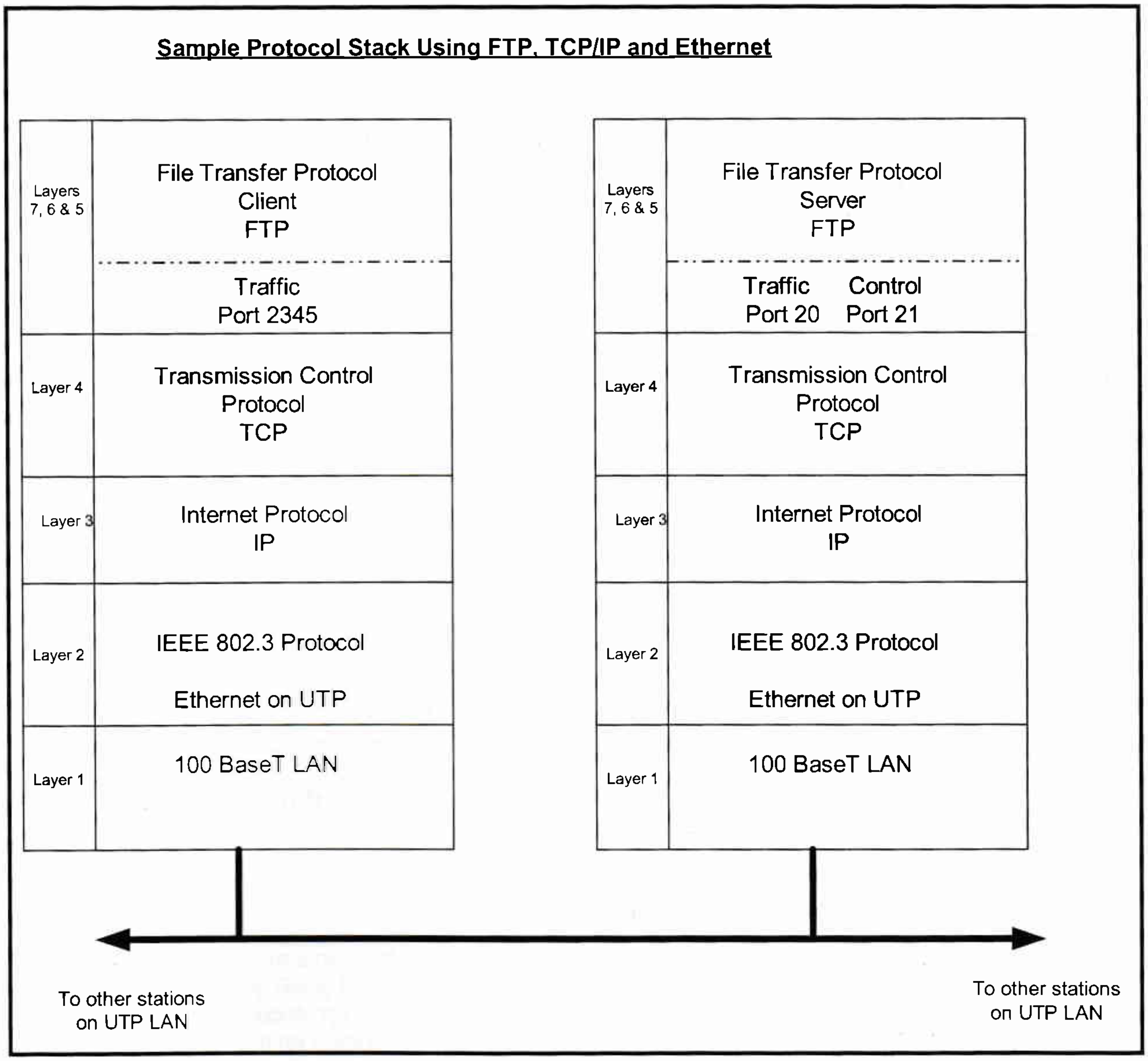


Figure 1-7 An Implementation of TCP/IP on Ethernet

D: Channel Access Methods

1) Definition of the Channel

A Channel can best be understood as the path used to connect together the source and destination terminal equipment. It is the physical path which joins two active devices in a network. An example would be a T.V. channel, where the desired show can be selected by choosing the correct channel, at the correct time. In this example, the Channel supports many shows during the course of the day and the week, but only one show is on each Channel at any particular time. A T.V. show maybe said to a Baseband signal, because each show gets the full bandwidth of the Channel while it is on. The Channel may also be described as a Time-Division Multiplexed channel, as each show has a specific time slot it may use, such as 7 to 8 PM on Friday nights.

In this example, the Channel could consist of the T.V. studio, an on-air radio transmitter, the receiver at a cablevision office, the translation equipment in the cable vision office which puts the signal onto the coaxial cable, which then provides cable T.V. service to its customers T.V. receiver. In this example a number of Links (e.g. the coaxial link between the cable company and the home, or the on-air link) are used to form one Channel. A simpler example is the Channel between two people talking on the telephone. Here the links would be the subscriber's loop, trunks between the telephone switches, and possibly fiber optic underwater links for calls to other continents. The Channel would be all the links required to connect the two telephone sets together.

A Channel may also be formed from a Broadband path. In this case the path may divided into two by Frequency Division Multiplexing. Returning to the T.V. example above, the various government agencies have assigned a particular band of frequencies to the broadcast of T.V. signals. In the case of Channels 2 to 6 they occupy the radio spectrum from 54 Mega-Hertz to 88 MHZ. This 34 MHz band is subdivided into 5 Channels of 6 MHz each, allowing 6 different shows to be broadcast simultaneously.

Another example of Broad-banding a path is ADSL on a telephone loop. The loop can carry up to 1 MHz of bandwidth, but only 3 kHz are required to transmit the voice signal on a phone. The frequencies above this level may be used for a high speed digital signal, permitting both an internet connection and a telephone conversation simultaneously. Each signal occupies its designated frequency bandwidth, and does not use any of the other signal's frequencies.

In general, most Local Area Networks provide a single Channel, which has to be shared amongst all the users on the LAN. Most often this takes the form of a Baseband signal, with Time Division sharing of the Channel. In order to gain access to the Channel for transmitting a message, a number of Channel Access protocols have been developed. The most common types are Contention Access, Poll and Select Access and Token Passing Access.

2) Contention: CSMA/CD

The basic concept of contention access is that the first station to gain access to the channel gets the Channel, provided no other station is already using the channel. The most common implementation of this is on Ethernet networks, where contention is enforced by using Carrier Sense, Multiple Access/ Collision Detection. This access method is often used on Bus topology, where all the work stations are required to share a common physical path to communicate.

The contention part comes in the Carrier Sense process. Say Station A wants to gain access to the channel, it first has to "listen" on the channel to determine if any station is currently using the channel. If the channel is already in use, the Station A will hold its transmission, but continue to listen. Once the previous message is sent, the Station A waits a short time (the "inter-frame time") and then starts sending its' message. For the duration of the message, which in IEEE 802.3 is a maximum of 1526 octets, Station A has sole use of the full bandwidth of the channel, a 100 MHz on Category 5e cables. At the end its message (or the maximum size frame), the Station A stops transmitting, and another station can then access the channel.

The second part of CSMA/CD is the multiple access characteristic of the protocol. All work stations have equal access to the channel; there are no priority stations or privileged stations which can preferentially access the channel.

The third concept embedded in CSMA/CD is the process to be performed when a collision is detected. In Ethernet, collisions are to be expected; there is no way to prevent two (or more) stations from trying to grab the quiet channel. The object is to ensure that the network can be restored to orderly operation when a collision does occur. This process starts when both colliding stations put out a jabber signal, which all listening stations will receive as a "collision detection" signal. The stations waiting for access to the channel will then delay trying to access the network for a random amount of time. The station with the shortest random time then accesses the channel and sends its message.

3) Poll and Select

The Poll and Select method of gaining access to the channel requires a single Host or "master" station which controls all the communication on the network. The Tributaries or "drop" terminals can not initiate a call, but must be permitted to send or receive traffic. This style of access is often implemented on tree-topology.

The Host performs a regular "Poll", which is similar to a roll call of all the drops, which ensures that the tributaries are active and capable of receiving or sending traffic. When a Tributary has to send a message, the Tributary will respond to its poll with a request to send traffic. The Host will permit the message to be sent, and either accept the message (if it is for the Host) or will buffer it for retransmission to another Tributary. If the message is for another Tributary, the Host will "Select" the Tributary and forward the message on to the destination.

Although common in Wide Area Networks, this form of Channel Access is not common in Local Area Networks except for the IEEE 802.4 Manufacturer's Automation Protocol, which is used to operate assembly line robotics. Poll and Select is most often implemented on networks with a Tree Topology.

4) Token Passing

The last form of channel access common in Local Area Networks is Token Access. Here an "Idle" token is passed from station to station in a predetermined order. If a station has traffic to go, it will remove the idle token, and send out a "Data" token, complete with the information to be sent. Each station in turn will receive the data token, and pass the token onward if is not for that particular station. When the data token reaches its destination, that station will pass the message up its protocol stack. It will also exchange the source and destination addresses in the data token, and mark the token as "Read". The read token then gets passed along to the remaining stations, eventually reaching the originator of the message. This station accepts the message, recognizes the read token as being a copy of its original message, thereby confirming receipt of the message at the target station.

Token passing networks are often implemented on Ring topology, but are also possible on a bus or tree topology. Token Passing networks tend to be more secure, and are popular with banks and other organizations concerned with security. An added feature of Token passing is that selected work stations can be prioritized, and capable of forcing their messages to be sent ahead of another, lower priority station.

E: Topologies

1) Physical or Logical shape of the network

The topology of a network refers to the shape formed by the channels and the physical equipment, and takes two forms. The physical topology is defined by the physical relationship of the work stations and the physical media, whereas the logical topology is defined by the operational shape of the network. It is common to find the physical and logical topologies are different. See Figures 1-8 and 1-9

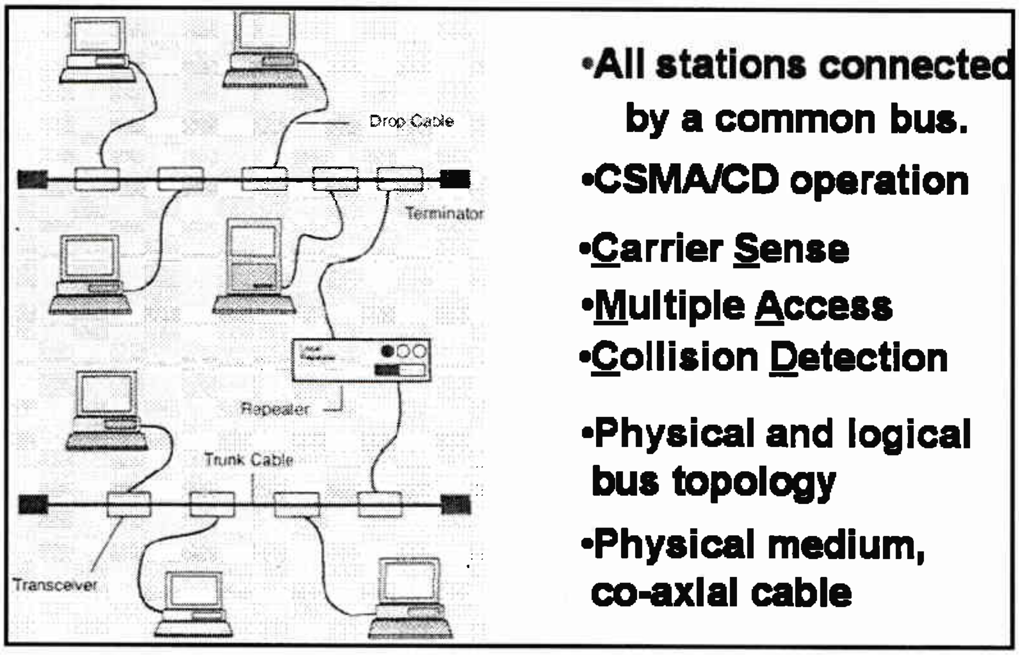


Figure 1-8 Ethernet on a Physical and Logical Bus

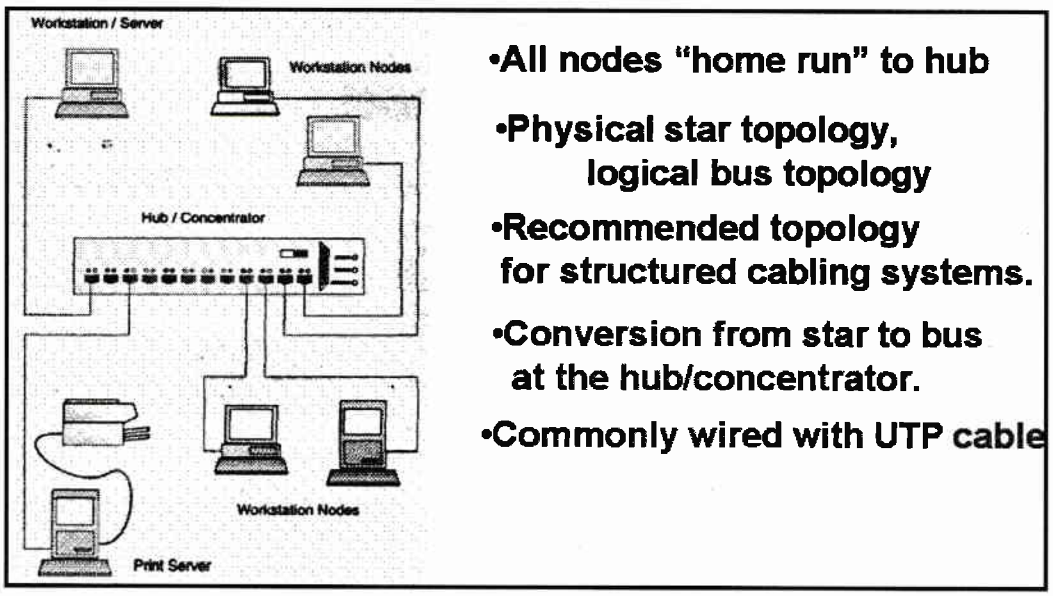


Figure 1-9 Ethernet as a Physical Star and Logical Bus

The Structured Cabling System defined by national and international standards states that the preferred physical topology is a Star, with the physical media connecting the various networked devices by cables which all home in on a common location. These "Home Run" cables are then cross connected to active centralized equipment which then provides the logical or operational shape of the network.

In older legacy type networks, the physical cabling had to support the physical and logical topologies of the network desired, but this meant that the cable structure had to be removed and replaced whenever the user wanted to change or upgrade the network. Many older buildings still have the obsolete cabling in place for the three or four networks which had been used previously.

With the advent of a Structured Cable standard, the stake-holders in network, that is the cable manufacturers, the software developers and the computer hardware developers now have an established physical standard which they can aim their future developments towards.

2) Peers, Host (Master), Tributaries

The type of workstations in the network will largely determine the logical topology of the network. Peers all have equal access to the network, which they share with other peers. Notice that this is a different use for the term peer than in the "peer to peer" network. With this definition of the term, even Client/Server pairs on an Ethernet network are really peers, in that the server and client have to share the single bus channel with all the other stations on the LAN.

A master Host station does not have any peers. Only the Host can initiate or forward traffic. In this type of logical topology, the remaining work stations are called Tributaries (or slaves). Channel access is assigned by the Host during the polling process, which is when the Tributary polled may send traffic. The Host then will select the destination workstation for the traffic, and forwards the traffic to that station.

Do not confuse Master/Tributary relationships with Client/Servers. Clients on a LAN are capable of communicating with each other, without the need for a server and whenever they want, provided the transmitting station has access (CSMA/CD or Token passing) to the Channel. In a Master/Tributary relation, only the Master can initiate communication, using the Poll/Select access process, and total control of the communication Channels is held by the Master Station on the network.

3) Point-to-Point Topology

The simplest network topology involves two stations connected together in a physical point to point circuit. The logical shape may take the form of a peer-to-peer, where either station may initiate a data transfer, or a Host/Tributary operation, where only one end can initiate the transfer. The actual data transfer can proceed in either direction in this case, but has to be initiated by the Host.

A typical example would be a dial-up modem for Internet access. The computer at home operates as the Host, dialling out to the Internet Service Provider, establishing the connection, etc. The server at the ISP responds to requests from the Host, providing an IP address if Dynamic Host Configuration Protocol (DHCP) is used, and sending request for web sites to the Internet.

Although point to point networks seem to be a trivial example, most LANS use a point to point network to access the Wide Area Networks using bridges, routers, optical/electrical links, Asynchronous Transfer Mode equipment, or SONET.

In Figure 1-10 below Al and Bob have a point-to-point relationship. Provided the channel is full duplex, Al and Bob may each transmit and receive signals simultaneously. The actual channel in this case may be as simple as an Ethernet cross-over cable between the two NICs on the stations, or as complex as the Public Switched Telephone Network, with all its multiple switches, trunks etc. The main characteristic is that once the channel is set up (say on the PSTN) only the two work stations are active on the channel.

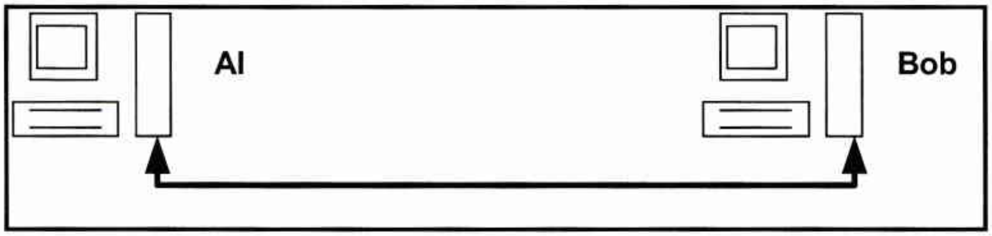


Figure 1-10 Point to Point Network

4) Multi-Point Topology

In a multi-point network, a single Host (Master) work station broadcasts its Poll and Selection sequences to all active Tributaries. Each tributary will respond when it is polled, something like roll-call in school. And like public school, the tributaries (the students) are not allowed to speak (that is send traffic) unless permitted to by the Host (teacher). See figure 1-11.

The analog with a classroom breaks down here, because even if Al wants to talk to Bob, Al's traffic must first go the Host, then get redirected with a Select sequence to Bob. Bob can not respond directly to Al's message, but is also required to transmit to the Host for redirection.

An example of this type of logical topology would be an airline reservation system. When Charlie a travel agent, has a ticket to buy, his work station has to wait until it is polled, when the request is sent to the Host. The Host would check the order, reserved the seat in its database, and then confirm the ticket purchase by selecting Charlie's workstation and sending back the confirmation number. The Host could also perform the poll/select process with a back-up host to ensure the main host has mirrored data in the back-up host.

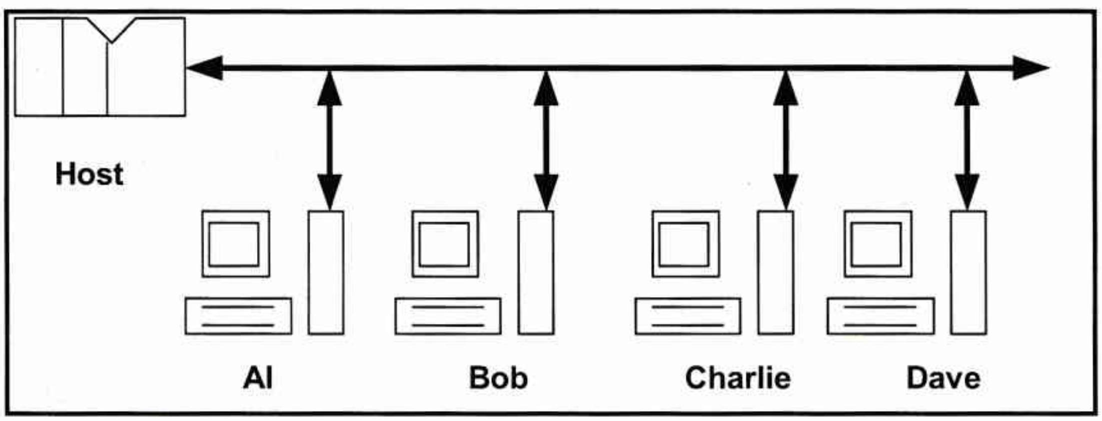


Figure 1-11 Multi-point Network

5) Bus Topology

A physical bus topology is one where all the stations share a common channel. Unlike the Multi-point network above, there is no controlling Master, but any station on the bus can initiate a call at any time, provided certain channel access rules are followed. Ethernet (IEEE802.3 and Ethernet 2) is the classic bus network, and the channel access method is CSMA/CD. 10Base2 (Thin-net or Cheaper-net) and 10Base5 (Thick-net) are logically and physically a bus, where the media used (50 ohm coaxial cable) was used to link all the stations together. This physical topology was not easily scaled upward, and adding a drop between two existing stations often required new cabling. See Figure 1-12

In Structured Cable Systems, the physical topology is Star wiring, with every station wired to a common location (the Telecommunications Room), where the logical bus operation is provided by an Ethernet Hub or a Layer 2 Switch. These Ethernets still operate as buses, but a physically wired as stars. The hub takes an incoming signal from one port, regenerates it, and sends it out to all the other ports. A Layer 2 switch reads the Media Access Control (MAC) address on incoming messages, and only forwards the message to the port which has the required destination address attached to it. See Figure 1-16.

The majority of Local Area Networks today are Ethernets, and many are still operated as physical buses, although new constructions are usually wired as stars. A physical bus network may also be operated as a Token Bus (using Token passing access), or a Tree or Multi-point network using Master/Tributary channel access.

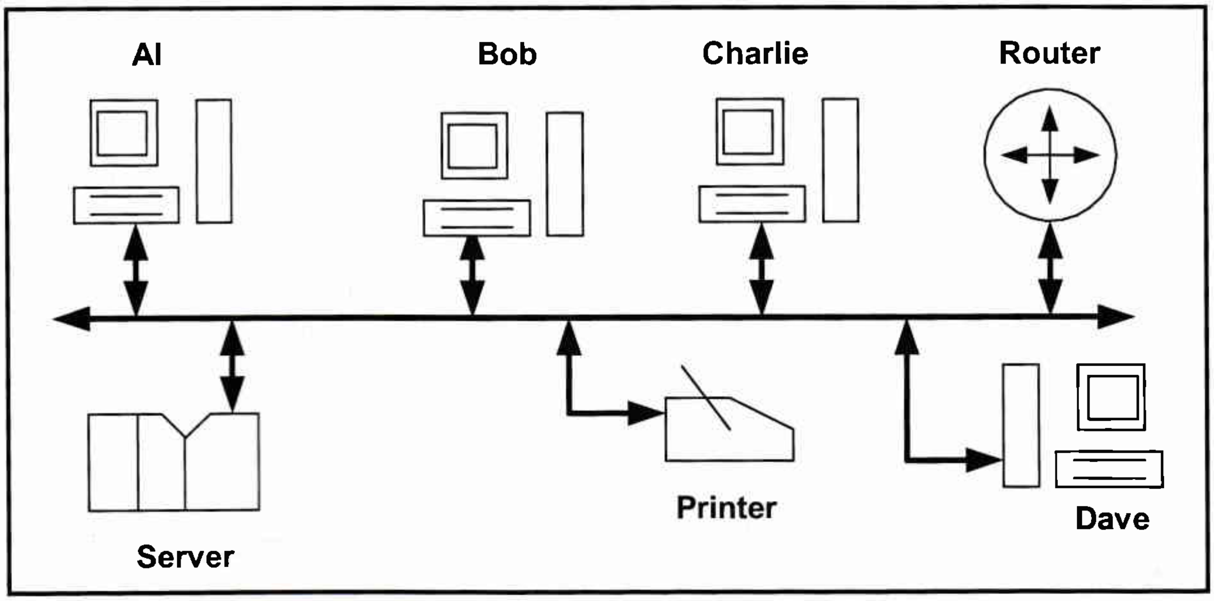


Figure 1-12 Bus Topology

6) Ring Topology

Ring topologies where once very popular as Local Area Networks, especially with banks and other businesses where security is very important. Rings were originally designed by IBM, to operate on Shielded Twisted Pair (STP) cables which had only 2 pairs of conductors, or Twin-axial cables, which contained 2 coaxial cables as a receive/transmit pair.

In the Ring, the message is passed from station to station, in a circular pattern. Each station in turn reads the message, and passes the message on if the message is not for that particular station. Once the message reaches the target station, the message is passed up the receiving station's protocol. A duplicate "Read" message is then placed on the ring, targeting the original transmitter. When the original transmitter receives the "Read" message, it gets confirmation that its message was received error-free. Rings normally have a Token Passing channel access, and are often referred to as Token Rings, where this term refers to the logical topology and the access method of the network. See Figure 1-13

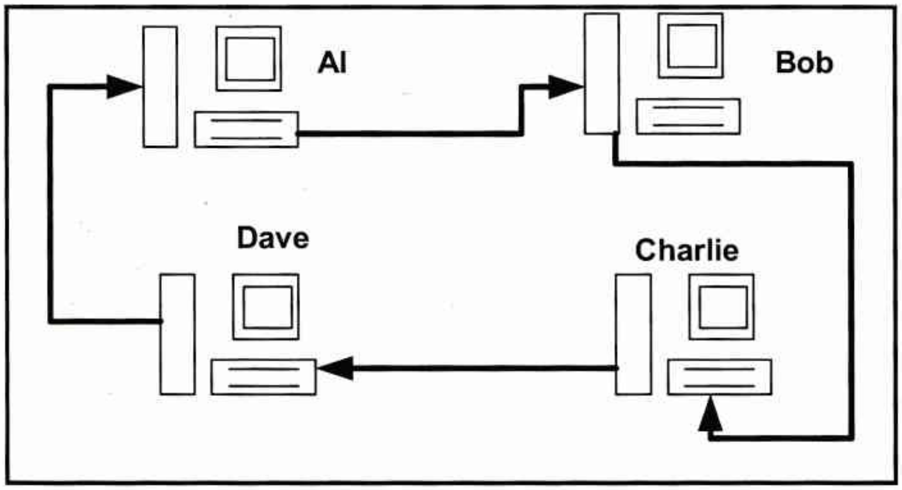


Figure 1-13 Ring Topology

9)) Tree Topology

The tree topology is not often found in Local Area Networks, except as automation robotics in industry. Stations on a Tree normally have a Master/Tributary relationship, to provide for an orderly flow on information. An industry example could be a drug company using assembly line techniques to package their products. The company needs to count the pills, place them in a plastic container, top with a tamper-proof seal, screw the cap on the container, place a label on the container, and lastly place them in shipping container.

Although these jobs could be done by hand, a more efficient and faster way would be through the use of a number of robotic machines, each performing a specific step in the process and controlled by the Master station. Networks of this variety could use IEEE 802.4 Manufacturer's Automation Protocol (MAP) as the Layer 2 protocol in use.

An important Wide Area Network which uses this physical topology is the IBM 3270 system, which many banks still use as their chosen network to pass information between the tellers and work stations to the main-frame computer which handles all traffic control and central storage of transactions. See Figure 1-14.

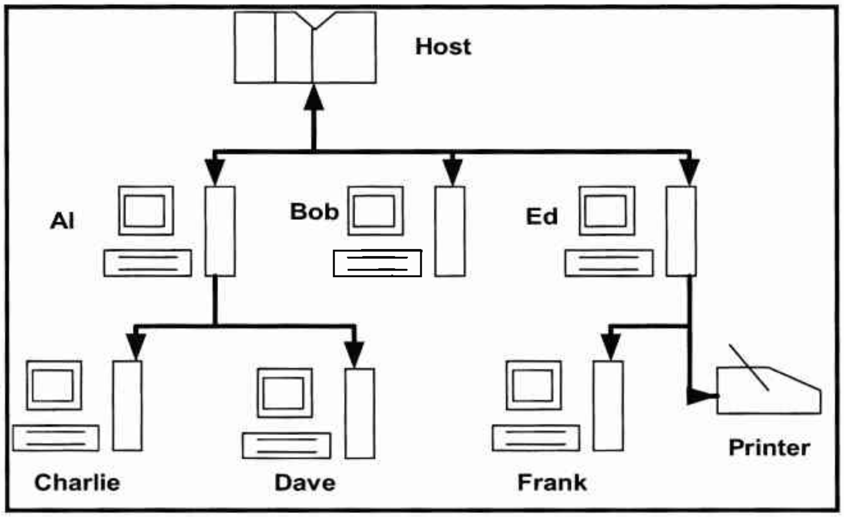


Figure 1-14 Tree Topology

8) Mesh Topology

Mesh topologies are not often found in Local Area Networks, as the main benefit of this shape is the redundancy in paths. For example, in Figure 1-15 below every node has a direct connection to every other node. Say the channel between Node A and Node B goes down (fails), the two nodes could still communicate by sending their messages to Node C or Node D, with a request for redirection to the destination. A few uses for this topology in a LAN would be to join sub-networks together using routers with redundant paths, or the use of mirrored Servers. A variety of channel access methods could be used in these networks, including Master/Tributary protocols and Token passing, but due to the multiple channels involved (6 in Figure 1-15), Point to Point protocols between each pair of Nodes is most common.

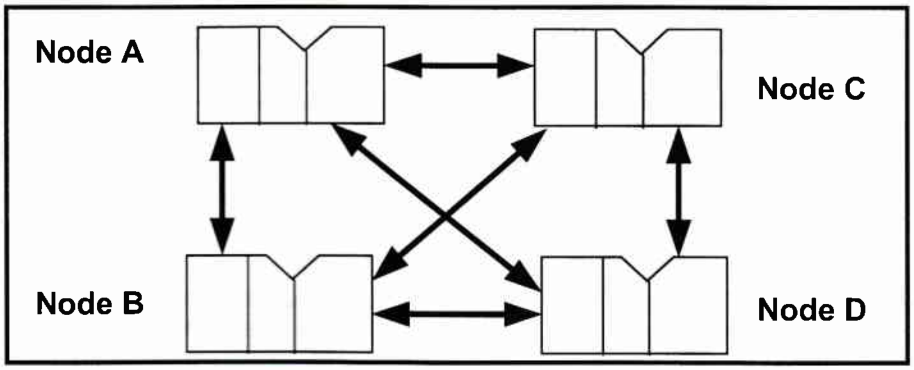


Figure 1-15 Mesh Topology

9) Star Topology

The star topology is the chosen physical shape that Structured Cable Systems take, because this physical topology is capable of supporting all the other forms of logical topologies currently deployed. A star shape will provide every work-station with direct link to a central location. From this location, the links can be joined together using an Ethernet Hub into a logical bus, using a Token Ring hub (also called a Multiple Station Access Unit MSAU) to create a logical ring, or a Host station and cluster control equipment to create a logical tree. Of course, point-to-point networks can also be supported.

A few varieties of networks work in a logical star, including E-mail servers, and the telephone system. Plain Old Telephone Systems (POTS) for example, requires that every telephone set is connected by a dedicated link (subscriber's loop) to the Central Office for switching. See Figure 1-16.

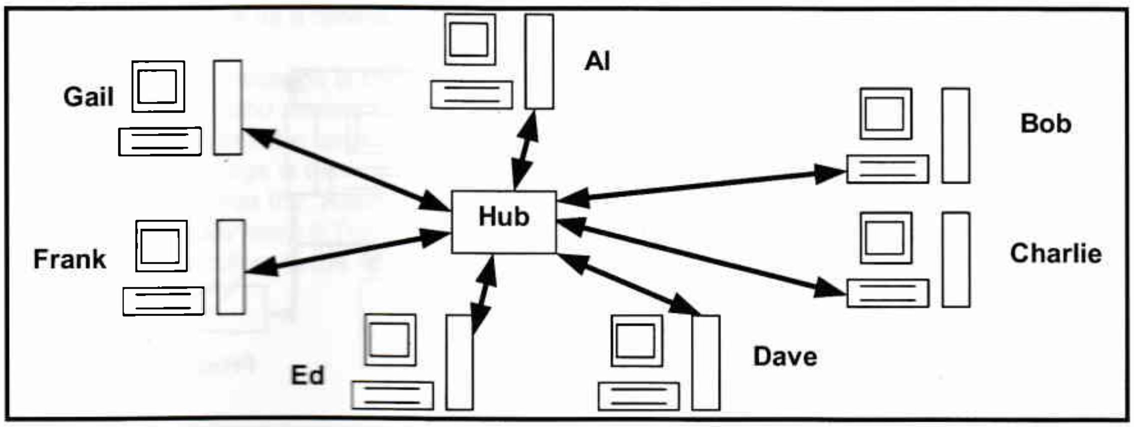


Figure 1-16 Star Topology Network

F: Addresses

1) Unique Physical Address (MAC)

In order to provide a reliable connection between two devices on a network, a number of address types are required. These addresses should be unique to the network, and may in fact be globally unique. The Physical address resides on the Data Link Layer (Layer 2) of the O.S.I. model, and its' function is to identify the physical path or the attached equipment which must be accessed for communication to start.

On an Ethernet LAN, for example, every Network Interface Card (NIC) has a globally unique address, the Media Access Control (MAC) address, a 48-bit identifier burnt into the NIC card, which can not be changed. It is the responsibility of the NIC Manufacturers to ensure no two NICs have the same MAC address. The first 24 bits of the MAC identifies the manufacturer, and the remaining 24 bits are a kind of serial number for that specific card.

Modems also have physical addresses, although they do not require a globally unique address, as modems generally only participate in Point-to Point networks (such as an on-ramp to the Internet), and as only two devices are communicating, both devices can recognize the source and destination of every message.

The POTS network also has a unique physical address for every one of its subscriber, namely the physical cable between the subscriber and the Central Office. A typical physical address for the telephone would be the cable number and pair that a particular telephone was connected to. The Cable may support a number of houses or businesses, or it may only support a single building, such as an office tower or an apartment. Cable 1234, pair 14 may go to Apartment 204, while cable 1234, pair 15 serves Apartment 205.

It is important to understand that the physical address identifies a physical location of the equipment. In the POTS example above, say Al moved out of 204, and wanted to take his telephone number with him. The new occupant of 204 would get a different phone number, but would be assigned the same physical pair Al formerly used.

2) Unique Network Address (Logical Address)

As we can see in the above paragraph, we will need a second address, one which is portable, that the user can carry with them, even when they move. In the case of the POTS network, this is the phone number that the telephone company has assigned the subscriber. Say Al's phone number was 604-525-1234 when he lived in 204. Now that he has moved into a house, he wants to retain the same phone number, so his friends and business acquaintances can call him.

This calls for a unique logical or network address which to a large degree can be made portable. This type of address may be globally unique, or just locally unique, and resides on the Network Layer (Layer 3) of the O.S.I. Model. For example, the phone number 525-1234 may exist in Alberta, but its area code will be 403. The POTS network can differentiate between 604-525-1234 in Vancouver and 403-525-1234 in Alberta by looking at the full address.

The most common type of logical address used today is the Internet Protocol address, a 32-bit address, usually express as a dotted decimal. An example would be 197.45.223.18. As diagrammed earlier, the IP protocol resides on the Network Layer, above the Physical and Data-Link Layers. When an IP datagram is placed on the Internet, the routers will check the IP address, and forward by the fastest or shortest means to the destination network. Once the message has been received by a router attached to the target network, the router must use an address resolution protocol such as ARP to map the logical, 32- bit address, to the physical 48-bit address for final delivery of the message to the correct workstation.

The use of the two addresses in conjunction with each other permits the user to change their physical location or change the attached NIC, and still retain the logical IP address. If the user wants to take her lap-top home with her, and move from her work network (and her assigned IP Address) to her home network, the logical address will change, but the physical address will not, and she has the ability to participate in two different networks, albeit at separate times.

Many logical addresses are assigned on a temporary “as required” basis. As an example, IP uses Dynamic Host Configuration Protocol to “lease” IP addresses to work-stations that do not require a permanently assigned logical address.

Below are shown the Logical and Physical Addresses in three separate communication systems. Figure 1- 17 shows the two address types as they apply in the Telephone Network. The physical address used is the cable and pair number of the subscriber’s loop. An alternate physical address could be the physical termination of the loop to the telephone switch at the exchange. The Logical address is the subscriber’s phone number.

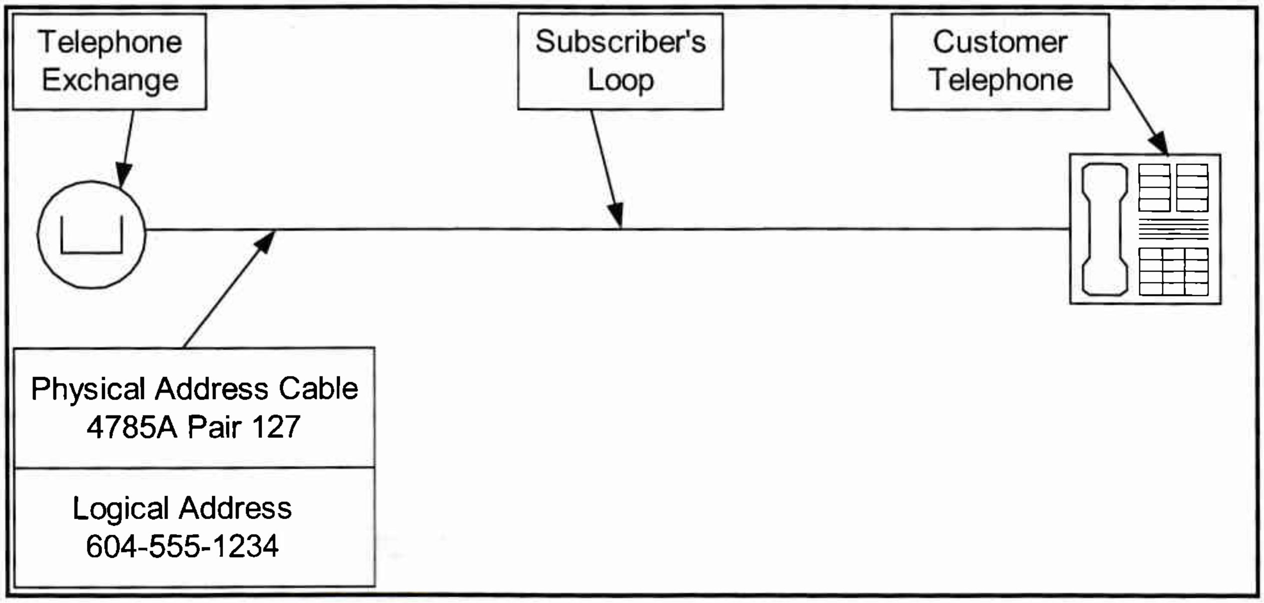


Figure 1-17 Physical and Logical Addresses in the PSTN

Figure 1- 18 shows the logical and physical addresses used in TCP/IP on an Ethernet LAN. Here the physical address resides in the NIC card at layer 2, and logical address is on Layer 3. An additional logical address resides on the layer 4/5 boundary (the “well-known port” number) which allows the PC to multi-task different upper layer protocols.

The use of IP logical addresses is best seen in the operation of Dynamic Host Configuration Protocol (DHCP). Many networks have more workstations than they have IP addresses, and rather than permanently assigning IP addresses, the address is “leased” for a short duration to a work station as required. In this case, the same workstation may have different IP address each day of the week. There is no fear that messages will get lost, as the physical (MAC) address does not change, and it the Router on the LAN maintains an Address Resolution Protocol (ARP) table mapping the permanent MAC address to the temporary IP address. ARP is of course, the protocol used to maintain this table.

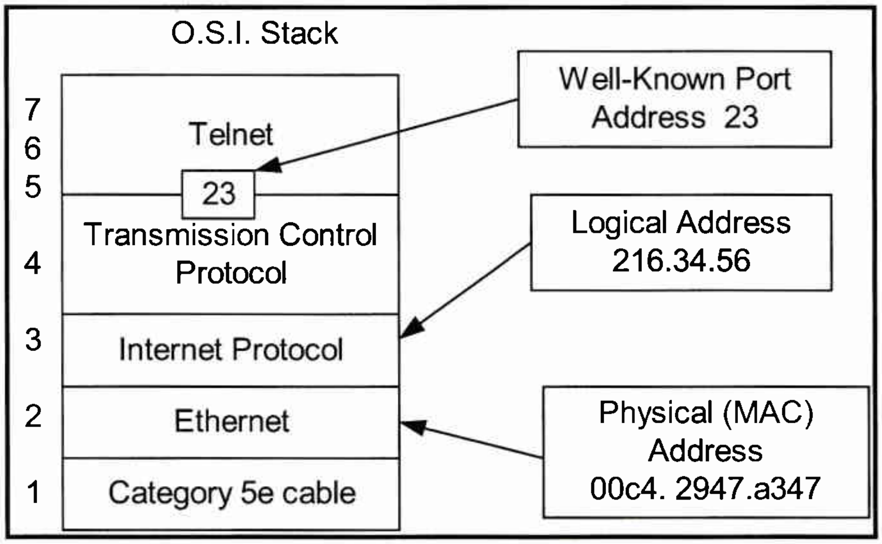


Figure 1-18 Physical and Logical Addresses in Ethernet & IP

Figure 1-19 shows the physical and logical addresses used by the post office. Here the physical address is the street address and city, while the logical address is the name of the source and destination people. If the person moves, the mail will still go to their old address, unless they pay to "redirect" their mail to their new location, a human process which is similar to ARP mentioned above.

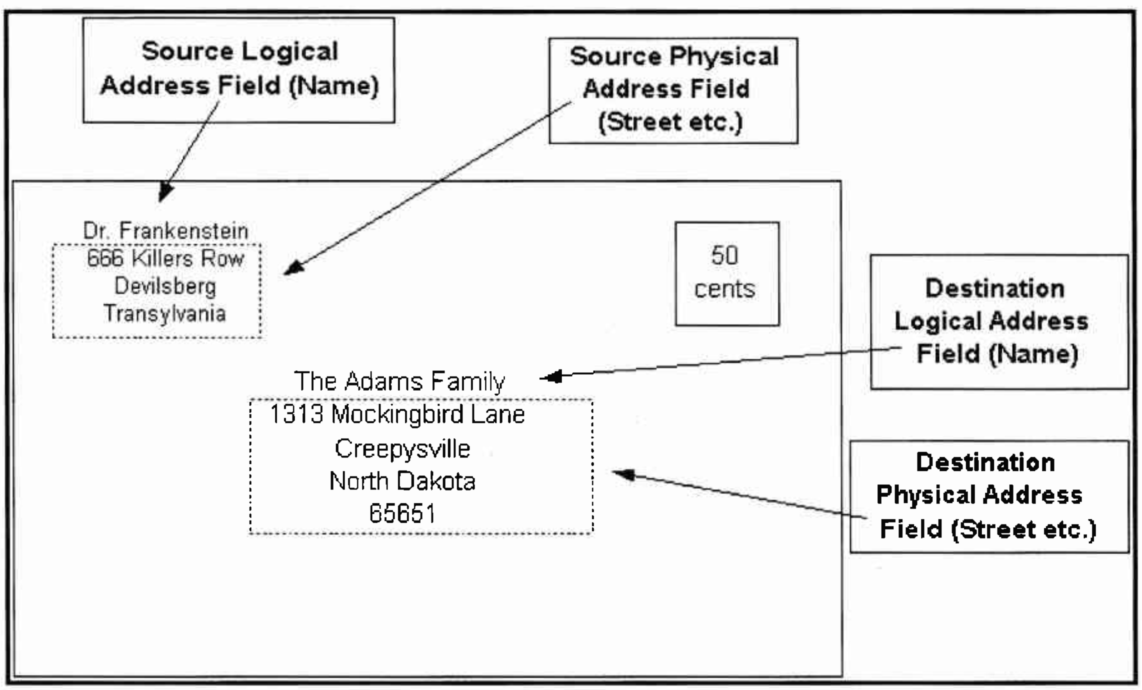


Figure 1-19 Physical and Logical Addresses in the Post Office World

G: Interfaces

1) Electrical, mechanical and functional interfaces

An interface can be viewed as any boundary between two devices, or software layers. Networking requires crossing many such boundaries, and the hardware and software developers have to meet the standard for each interface the code or equipment crosses. An interface may be a physical connection such as the RS-232 serial interface used in modems or the NIC interface for an Ethernet network, or a software connection like the boundary between the Transport and Session Layers, which uses well-known port address to provide multi-tasking capabilities.

The interface may provide for common electrical parameters such as voltage levels, line code type used (i.e. definition of a logic zero or a logic one), speed and pulse shape, to ensure all devices attached to the channel "speak the same language". The mechanical shape of the physical connection is also standardized as to its shape, size, number of connectors etc. The T568A outlets used in UTP networks provide a ready example, as do the IBM data connectors used in legacy networks.

Lastly, the functional use of the physical connections (for physical interfaces) or the Application Program Interface (API) handles must also be standardized. An example of this type of standardization can be seen in the software boundaries between the various layers in the O.S.I. model. A programmer can write any code they want which is sufficient to do the job, so long as it meets the next layer in the proscribed manner.

2) Types of Mechanical Interfaces

a) T568A and T568B Telecommunication Outlets

Structured cable systems based on 100 ohm UTP cables have been standardized to the use of an 8-position, 8-conductor Insulation Displacement Connector (IDC) which resembles a standard household telephone outlet, but with more conductors. Both the T568A and T568B use the same physical hardware (often mistakenly called a RJ45 jack), but the cable conductors are wired in two different configurations.

The T568A outlet is used in the International and Canadian standards, while the T568B is an optional variant in Canada, and is most common in American businesses in the U.S.A. Both configurations provide for the termination of 4 physical pairs (8 conductors) in the outlet. See Figure 1-20.

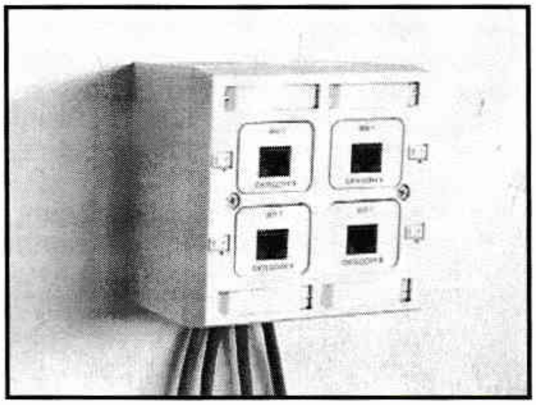


Figure 1-20 Four T568 Outlets in a Surface Mount Module

b) Network Interface Card

The Network Interface Card for modern Ethernet networks is equipped with a T568A or T568B outlet in order to interface with the 100 ohm UTP physical network. Some NIC cards still have a BNC (50 ohm coaxial connector) for use with Thin-net coaxial networks. The NIC card provides the Data Link Layer 2 functions (e.g. the MAC address, calculating the Frame Check Sequence, etc.) and interfaces with the Physical Layer 1 of a metallic cable.

The typical Ethernet NIC can transmit 10/100 Base-T in a serial fashion, using only two pairs, conductors 1/ 2 and 3/6 as a transmit/receive pair. Some implementations of IEEE 802.3, such as 100-Base-T4 or 1000-Base-T, use all four pairs of conductors, send and receive data in parallel, 4 signals at a time. Some high speed networks even send full-duplex, which means that a single device can be transmitting at the same time as it is receiving a message from another computer.

Other NIC cards may have coaxial connectors for 10-Base-2, 15 pin DB-15 connectors for 10-Base-5, 8p8c (telephone type) connectors for UTP networks, or twin-axial or STP connectors for IBM Token Ring networks. See Figure 1-21.

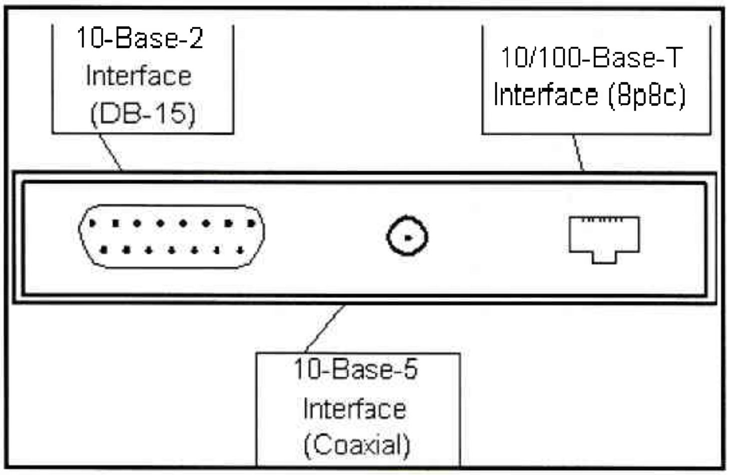


Figure 1-21 NIC card with 3 different LAN interfaces

c) IBM Data Connectors

IBM was one of the first large players in Local Area Networks, and produced a number of proprietary network systems such as the 4 Mbps and 16 Mbps Token Rings. This protocol has now been standardized as the IEEE 803.5. Originally, these networks were designed to run on shielded 2-pair cables. A special connector, the IBM Data Connector, was the physical interface chosen for these networks.

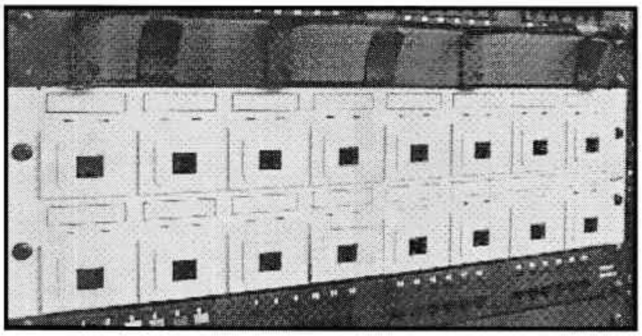


Figure 1-22 Rack Mounted IBM Data Connectors

With the advent of the IEEE 803.5 protocol and UTP networks, equipment manufacturers developed baluns to the convert the unbalanced IBM equipment to work into a balanced 4-pair, structured cable system.

d) Serial Peripheral Interfaces

A common interface found on tower computers is the DB-9 or DB-25 style RS-232 serial interface connector, which may be connected to a modem, or other serial device. It may have between 3 and 25 active conductors, depending on the service provided, although most devices will use less than 9 conductors. See Figure 1-23. Additional serial interfaces include the USB (Universal Serial Bus) connector, which can access many addressed peripherals on the same interface, and the V.35 high speed interface which may be found on carrier type equipment such as T-1 systems.

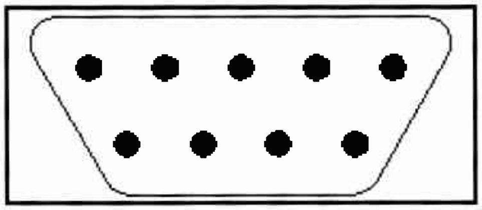


Figure 1-23 Serial DB-9 Interface

e) Parallel Peripheral Interfaces

Most computers also have a parallel interface port, also on a DB-25 connector, which is used to connect to a parallel device such as a printer. Eight bits of information are sent to the printer at one time. Although highly efficient and fast, parallel transmission suffers from clocking issues if the physical link is too long. For this reason, parallel transmissions generally only occur on relatively short distances of perhaps a few hundred meters. See Figure 1-24.

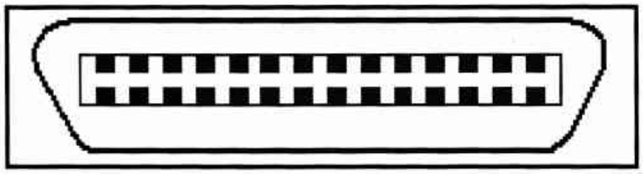


Figure 1-24 Parallel "Centronics" type Interface

f) Fiber Optic Interfaces

Unlike the all the interfaces so far discussed, fiber optics do not have electrical characteristics. Instead the light transmission characteristics become critical to the interface performance. A number of different types of connectors and splices for optical fiber are currently available, with the SC568 connector type being the preferred standard under TIA/EIA-568B.

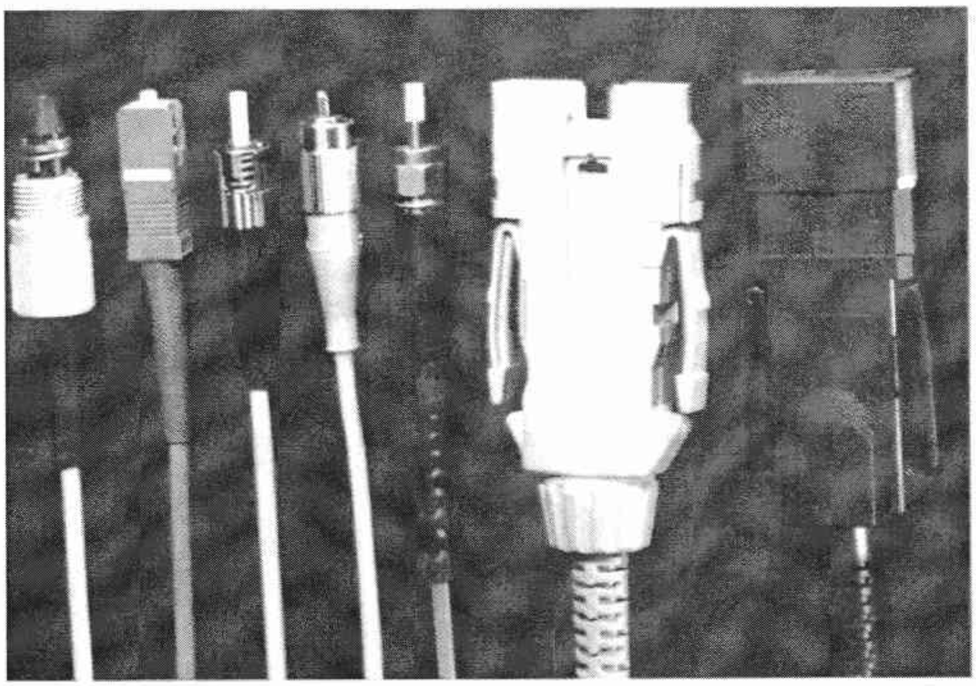


Figure 1-25 A Selection of Fiber Optic Interfaces

Section 1 Summary

Commercial requirement for a standard physical network

Recognized Media and Cable Infrastructure
Performance Standards
Flexibility, Adaptability and Scalability

Open System Interconnect Model

7 Layer Model
Structured Cable Systems are on Layer 1, the Physical Layer
Network Interface Cards are on Layer 2, the Data Link Layer

Communication Protocols

Agreed upon rules for communicating
Frame and field enforcement
Encapsulation

Channel Access Methods

Contention: Carrier Sense, Multiple Access/Collision Detection (Ethernet)
Poll and Select
Token Passing

Topologies

Physical and Logical Topologies
Bus Topology (Ethernet)
Ring Topology (Token Rings)
Physical Star Topology (Ethernet)

Physical and Logical Addresses

Media Access Control address
Internet Protocol address

Interfaces

Electrical, Mechanical and Functional parameters
Physical and Software Interfaces
T568A and T568B Telecommunications Outlets

Section 2: Legacy Networks

A: Vendor & Function Specific Networks

Prior to the advent of inexpensive desk-top computers in the 1980s, the only Local Area Networks which existed were either Token Ring networks (at 4 Mbps), sometimes built from dumb terminals, or point-to-point networks (up to 9.6 kbps) built up separately with no interconnection between them.

Banks and similar business would build an intra-building LAN which served their particular need, say the requirement to copy money transactions and to store the information related to each and every transaction. Memos and company directives were distributed by the company version of snail mail, consisting of written memos sent to the recipients by the office mail delivery systems. Wide Area Networks supplemented the LAN by use of a single node in every office, which was connected to a main-frame computer at the (far-distant) head office by the use of a dedicated point-to-point modem circuits, or a multi-point networks using Poll and Select access protocols. These two networks would work in conjunction with each other to store daily traffic on the memory storage system of the LAN, with the wide area network transmitting the daily information to the main frame by use of the WAN network after business hours.

Whatever the source of the cabling, these early networks were vendor and function specific, and a cable structure built for a specific vendor or product could not normally be adapted to another network topology or protocol.

B: POTS Networks

The other major network which existed at this time was the telephone network. During this time the phone companies provided the internal cabling in every business and residence requiring access the Public Switched Telephone Network (PSTN). The telephone companies in turn provided the telephone sets and in-building access to each phone set. The telephone system provided both voice and low speed data communication (rarely usable above 9600 bps) between sites. This early cabling, and the limited functionality of the network, is often referred to as the Plain Old Telephone Service (POTS). Features we take for granted now, like Caller ID, Last number redial and Call Forwarding, were not available

As the main building cable installer, the telephone company provided the majority of media, in the form of non-category cables, which businesses tried to use to satisfy their need for networking. And as the only egress to the outside world, the telephone companies had a monopoly on access to the outside world. In addition, if another WAN supplier was contacted, that supplier had to cable in an acceptable media for the network.

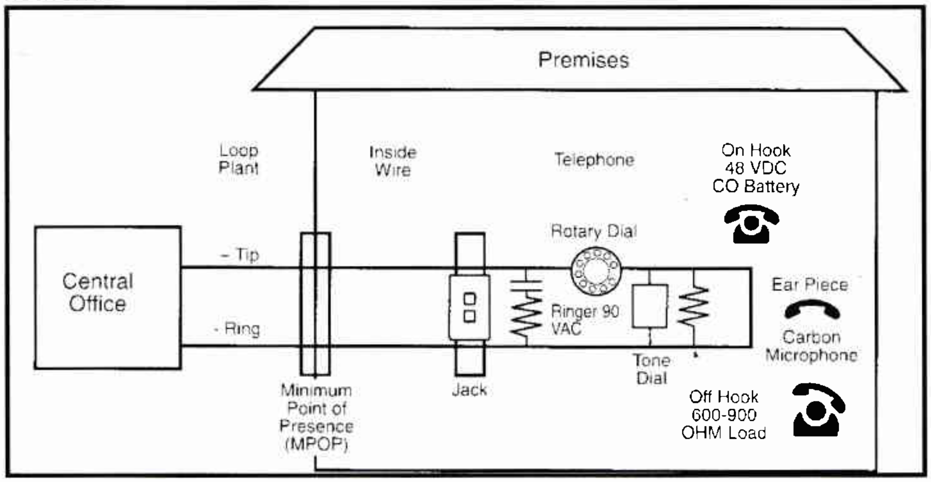


Figure 2-1 POTS wiring in the Residence

As a result of these limitations and implementations, the physical media of these legacy networks which could be 2-wire STP, 2, 3 or 4-wire UTP cabling, or coaxial cable, still exist in a lot of older buildings. Structured Cable Systems cannot use the existing cable infrastructure because the cables fail to meet the performance standard required of modern high speed networks, and do not have the physical topology of required to support a Structured Cable System.

When desk top computers became a common piece of equipment in the business world, the need for linking all the stations within a business became apparent, and the benefits of a LAN become more evident. The first advance of the LAN was the establishment of low speed Ethernet networks at 10 Mbps, These early networks supported what was then considered a High speed system, carried on 50 ohm coaxial cables. The individual stations could then update a local server with the day's action, which in turn could then be uploaded to the WAN as required. Advances in networking eventually lead to number of different physical media which would support the newer networks. As a result, many buildings have remnants of many former networking media, in the form of POTS cabling, coaxial cables and STP cables. These cables lie unused in the darker spaces of the building as the cost of removing the cables was seen as unnecessary by the user or building owner.

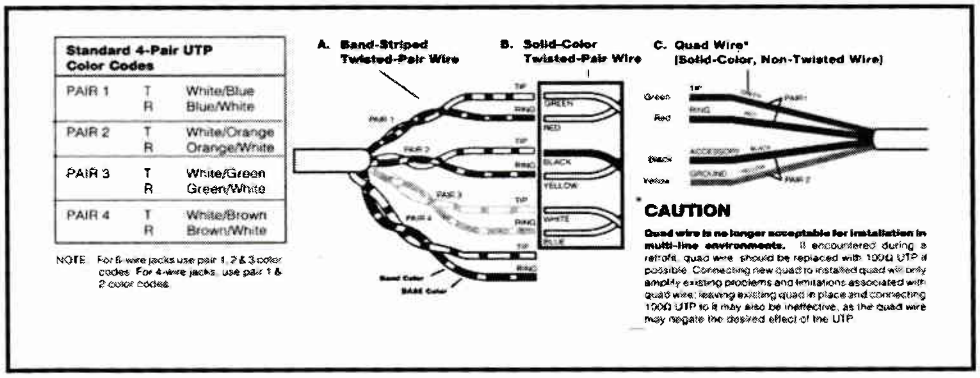


Figure 2-2 POTS Colour Code to Structured Cable Colour code

The object of POTS cabling was to provide at least two pairs of conductors to every location where a telephone could be desired. The actual telephone locations were largely decided by the building contractor, with more or less adequate coverage. In B.C., the telephone companies started providing 25 pair cables to each phone location, which provided a large growth factor to the phone, fax or data networks. Unfortunately, the POTS non-category cabling provided by the phone company will not support a 16 Mega-Hertz bandwidth required by 10BaseT networks.

POTS cabling can be successfully used as the media to support T-1, Integrated Services Digital Network (ISDN), and Asymmetric Digital Subscriber Line (ADSL) all of which run at 1.5Mbps or less.

C: Wide Area Networks

Wide Area Networks (WAN) are considered to be any network with distances beyond those of the LAN or Municipal Area Networks. This is not just an arbitrary distinction. When analogue or digital traffic has to be carried for long distances, the protocols and equipment used in LANs will no longer work. For example, CSMA/CD can not function efficiently on a long Channel because of the time required for the signal to travel the great distances. CSMA/CD works on 90 meters because the delay times are around 2 microseconds. On a WAN of perhaps 1000 Kilometres, (e.g. Vancouver to Calgary) the delay times are upward of 20 milliseconds. Other issues also come into play, such as reshaping and re-amplifying the signal.

Legacy Wide Area Networks often made only a single appearance in the subscriber's premise. The carrier company providing the WAN service would typically install a 4-wire pair (i.e. two twisted pairs of conductors) to a specified location where the modem, line driver or other electrical interface would be situated.

This appearance would be connected to a particular station, which could act as a Tributary to the WAN, (Figure 2-3) or to some digital sharing device, which would split the incoming WAN to a number of local stations (Figure 2-4). In either case, the local members of the WAN were limited to a few (often one) station.

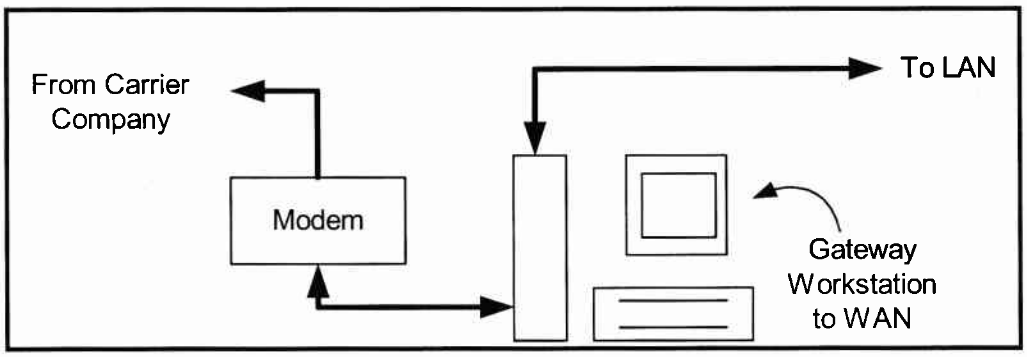


Figure 2-3 WAN Tributary as Member of LAN

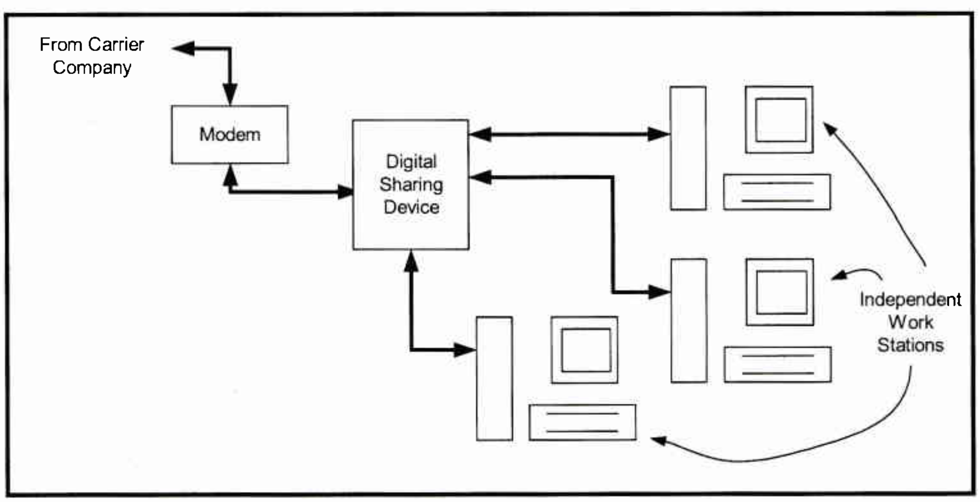


Figure 2-4 Multi-drop Stations as Members of WAN

D: Legacy Local Area Networks

1) IBM Token Ring on STP

One of the first LANs in wide use was the IBM Token Ring, operating at 4 Mbps initially and later upgraded to 16 Mbps. Token Ring networks are still popular with banks and other businesses which are concerned with security issues. Legacy Token Ring networks appeared on a number of physical media, including coaxial cable, Twin-axial cable, and 150 ohm shielded twisted pair (STP) having 2 pairs.

Adapters called baluns (for balanced unbalanced transformer) were developed to permit equipment designed to work into coaxial, unbalanced lines to operate on balanced twisted pair cables.

2) 10Base-2 and 10Base-5

The first versions of Ethernet were developed by Digital Networks, Intel and Xerox, the DIX version of Ethernet, now referred to as Ethernet 2. This legacy network was designed to work onto a 50 ohm coaxial bus backbone (the Segment). 10Base-2 was also called Thin-net or Cheap-net and was supported by a physically smaller cable running a maximum distance of 185 meters. The 2 in the name came from the approximately 200 meter segments permitted.

10Base-5 ran on a thicker 50 ohm coaxial cable, and often referred to as Thick-net. 10Base5 networks could support 500 meter segments. Although no longer installed as segments supporting an active population of workstations, 10Base5 is common as bridging network, joining distant 10 or 100 Base T networks together.

10Base-2 and 10Base-5 networks required 50 ohm terminators on both ends of the cable segment, and all unequipped locations had to have barrel connectors rather than the tee-connectors commonly found. A common problem with these two networks was reflections on the line, caused by unterminated ends and open tees. These reflections would appear like traffic, causing echoes on the line and higher than expected collision rates. These two LAN types have largely between replaced by 100 UTP Structured Cable Systems.

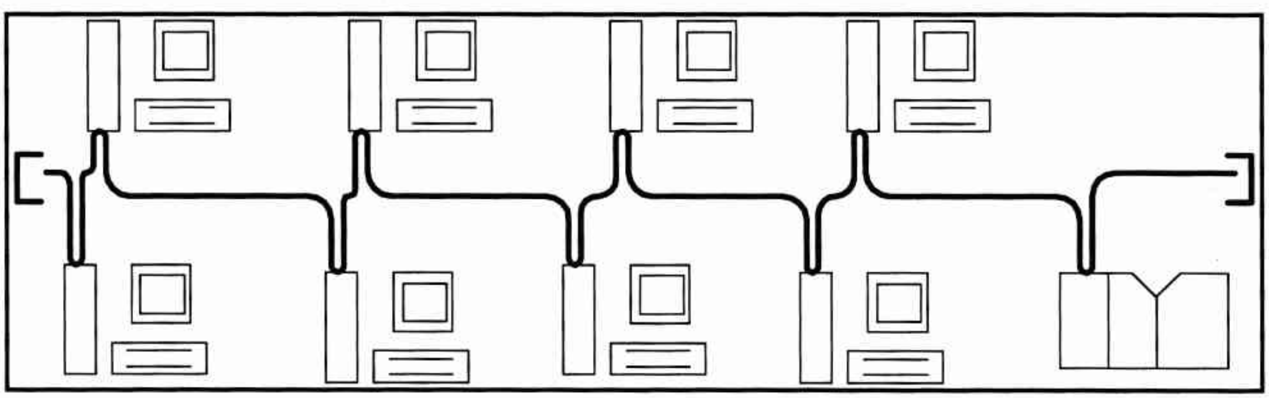


Figure 2-5 10Base-2 and 10Base-5 Networks

3) PBX telephone system

Since the 1970's, the use of customer owned telephone switches, called Private Branch Exchanges (PBX) have been an economical method of providing telephone service to business. One of the main ways businesses benefit through having their own PBX is by reducing the cost of leasing many expensive trunks to the premises. Instead of having to provide a separate outside line to every employee, a smaller number of trunks would suffice to provide outside access to the user as required.

Legacy and modern PBX systems used the Star topology to provide a single channel from the PBX to each telephone set. In a way, the PBX cable topology supplied the model for Structured Cable Systems.

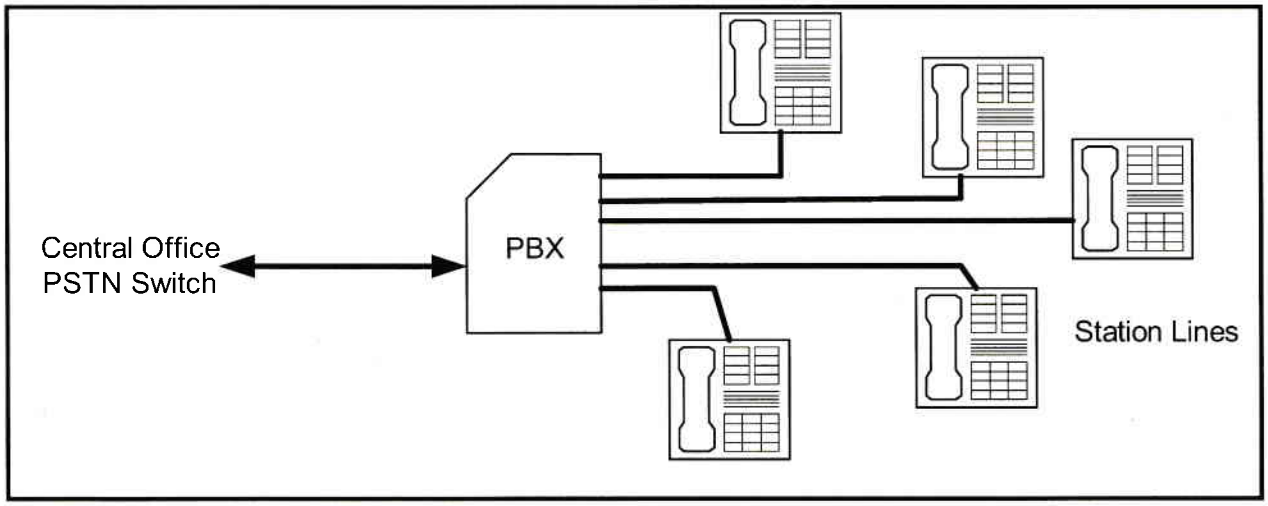


Figure 2-6 The PBX in a Business

Section 2 Summary

Legacy Networks

Function and Function Specific
Built as required

Public Switched Telephone Network (PSTN)

Plain Old Telephone Service (POTS)
Non-standard cabling and color codes

Wide Area Networks

Point to Point Dedicated Service

Legacy Local Area Networks

Early Ethernet LANs
10Base-2 “Thin-net”
10Base-5 “Thick-net”
Private Branch Exchanges

Section 3: Structured Cable System Standards

A: ISO 11801 (in brief)

By the mid 1980's businesses were starting to have a Personal Computer (PC) on their employees desks, and a need to network the work-stations together became apparent. The International Standards Organization created from of a number of sitting committees and delegations from the various national standards organizations such as the Canadian Standard Association (CSA) and the American National Standards Institute (ANSI) took this matter into consideration.

At the heart of this matter was the requirement for a standard physical cable structure which would support the current and future requirements of the LAN. Vendor and product specific cable types and topologies did not have the flexibility required by changes in technology, improvements in protocols or increases in user populations. Additionally, the business community was finding the cost of re-cabling their premises to support an improved LAN becoming excessive.

The ISO realized that their 7-Layer Model required a standardized interface at the Physical Layer. After sessions with the software, hardware and cable manufacturers, an ISO standard, the ISO 11801, was created. This standard identifies the major issues of concern, including the need for establishing space requirements to support the LAN, adequate work area coverage to support current and future populations, a flexible topology, test parameters, grounding and bonding and a documentation process to record the "as-built" structure. This document was then taken back to the member nations, and eventually became, more or less, the national standard. All these documents are considered "living" documents, in that they are reviewed regularly, and updated to reflect the latest changes in LAN operation.

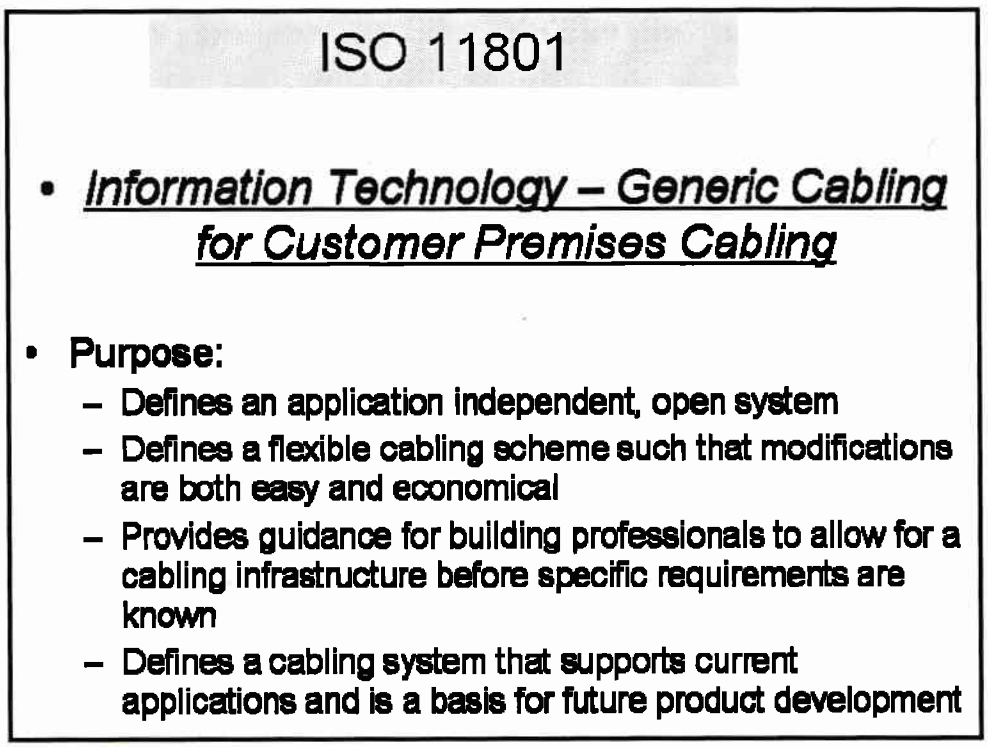


Figure 3-1 ISO 11801 Standard

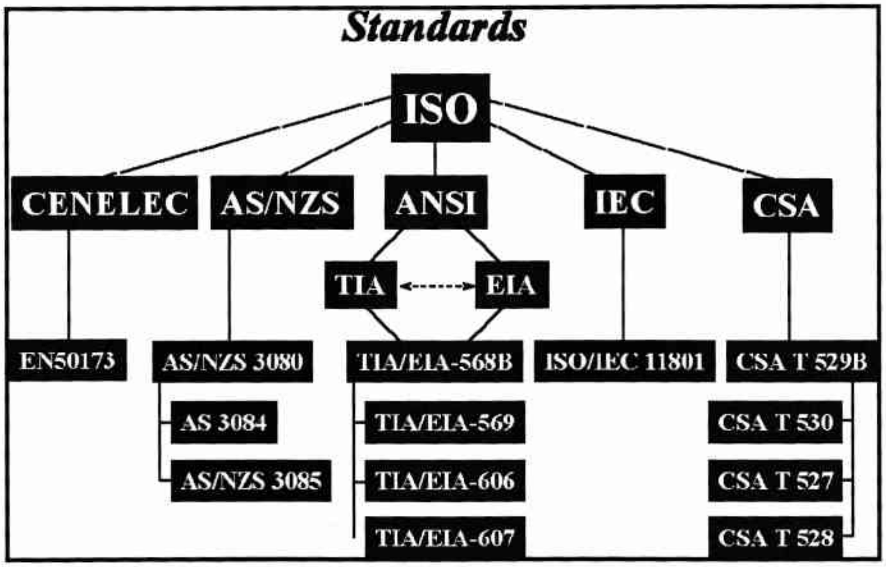


Figure 3-2 Relationship of National Standards to the ISO Standards

CENELEC is the standards body in France, and is used through most of the French speaking world. AS/NZS is the Australian & New Zealand Standards body. ANSI is the American National Standards Institute, which has the Electronic Industries Association (EIA) and Telecommunications Industry Association as sub-committees. The International Electronic Committee is the sub-committee of the International Standards Organization which covers telecommunications. The CSA is the Canadian Standards Association which establishes the standards for Canada.

In the case of Telecommunications standards, the CSA largely follows the TIA/EIA documents

B: <u>TIA/EIA 568B 569, 606 and 607 in brief</u>

In America, ANSI turned the creation of a national standard over to the Telecommunications Industry Association/Electronics Industries Alliance (TIA/EIA), a sub-committee concerned with telecommunications and electronic matters. After consideration of the existing practices in the U.S., this group brought out a number of standards, which although approaching the ISO standard, do not fully agree with it. The four documents are concerned with the cable structure and components required to create a structured cable standard, the building space requirements (largely for the building architects), grounding and bonding, and the record documentation process.

In Canada, the Canadian Standards Association (CSA) largely adopted the American documents, with only a few changes reflecting current practices in Canada. These documents are available for a fee through the CSA in Canada or the TIA/EIA in the U.S.

1) <u>Commercial Building Telecommunications Cabling Standard</u>

- In Canada the **<u>CSA T529B</u>** document
- In America the **<u>TIA/EIA 568-B</u>** document
- Horizontal and backbone cable details
- Topologies required
- Establishment of rooms for specific network functions
- Installation practices
- Methods of cross-connection cabling
- Cable transmission and performance standards

2) Building Facilities, Design Guidelines for Telecommunications

- In Canada the **CSA T530-M90** document
- In America the **TIA/EIA 569-A** document
- Acceptable pathways for telecommunication cables
- Horizontal and Backbone pathways
- Work area and furniture pathways
- Telecommunication Room functions, size and locations
- Equipment Room functions, size and locations
- Entrance Facility functions, size, physical access
- Multi-residence building considerations
- Fire-stopping and Grounding concerns

3) Design Guidelines for Administration of Telecommunications Infrastructure in Commercial Buildings

- In Canada the **CSA T528-93** document
- In America the **TIA/EIA 606** document
- Administrative concepts and component identifiers
- Creation of permanent "as built" records
- Linking the records of physical components
- Presentation of records, reports drawings and work orders
- Pathway and Space administration
- Wiring system administration
- Grounding and Bonding administration
- Field labelling and colour coding

4) Commercial Building Grounding/Bonding Requirements

- In Canada the **CSA T-527-94** document
- In America the **TIA/EIA 607** document
- Issues with electrical grounding and bonding
- Establishment of a separate grounding system for telecommunications
- Use of grounding bus-bars and grounding backbone conductors
- Labelling of conductors and components of the grounding system

C: TIA/EIA 568B (CSA T-529B) Document

The main document of the four is the T-529B (TIA/EIA 568B) document, which establishes good installation practices and the tests required to verify the passive cable structure will support the level of service it was designed for. This document was divided into 3 parts in the 2002 revision, with 568-B.1 covering copper cable concerns and 568-B.2 covering parameter testing of the copper systems. 568-B.3 covers the installation and testing of optical fiber cables, and is summarized later in this document.

A few minor differences exist between the Canadian and American documents, which do not concern us here. The following is a summary of the TIA/EIA-568B Part 1 Commercial Building Telecommunications Cabling Standard document, and as such is subject to errors of omission and interpretation. Where accuracy and completeness is required, refer to the original document.

1) Horizontal Cable

- The Horizontal cable extends from the W/A T/O to the Telecommunications Room (T/R) terminating hardware (Figure 3-3)
- Physical topology of the Horizontal cabling shall be a Star ("Home Run")
- Maximum length from T/O to terminating hardware shall be 90 meters
- Recognized copper cables are 4-pair 100 ohm Unshielded Twisted Pair (UTP)
- Recognized optical fibers are 2 fibers of 62.5/125 micron or 50/125 micron Multi-mode cable
- 150 ohm Shielded Twisted Pair (STP) although currently recognized, is not recommended for new installations
- Use of Consolidation Points (C/P) permitted
- Bridge taps, splices or splitters shall not be permitted on Horizontal cables
- Every work area shall have two Telecommunication Outlets, each supported by a separate 4-pair cable, or by two optical fibers
- These two outlets shall support:
  One Category 3 or better cable, and be metallic, and
  One Category 5e or better cable, which may be Multi-mode Optical Fiber
- A single Consolidation Point or Transition may be used on the Horizontal cable
- If Screened Twisted Pair (ScTP) used, the screen shall be bonded to a grounding bus-bar
- Grounding and Bonding requirements shall meet TIA/EIA 606 standard

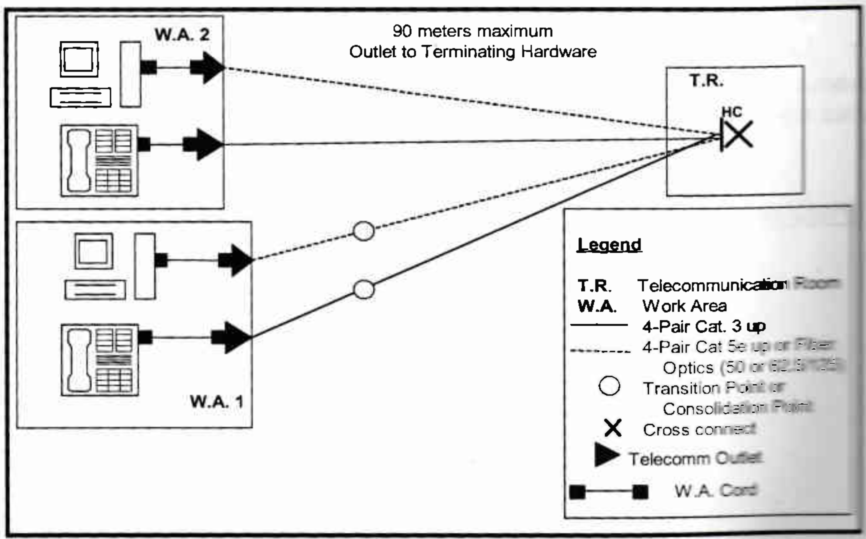


Figure 3-3 Horizontal Cabling to the Work Area

2) Backbone Cable

- The Backbone cables shall be terminated in, and provide interconnections between;
- The Telecommunications Rooms and the Equipment Room
- The Entrance Facility (E/F) and the Equipment Room
- Backbone cables may be provided between Telecommunications Rooms as required
- Physical topology of the Backbone cabling shall be a hierarchical Star (Figure 3-4)
- No more than two hierarchical levels of cross-connects permitted on Backbone cables
- Cross-connects for the Backbone may be located in the T/R, the E/R or the E/F

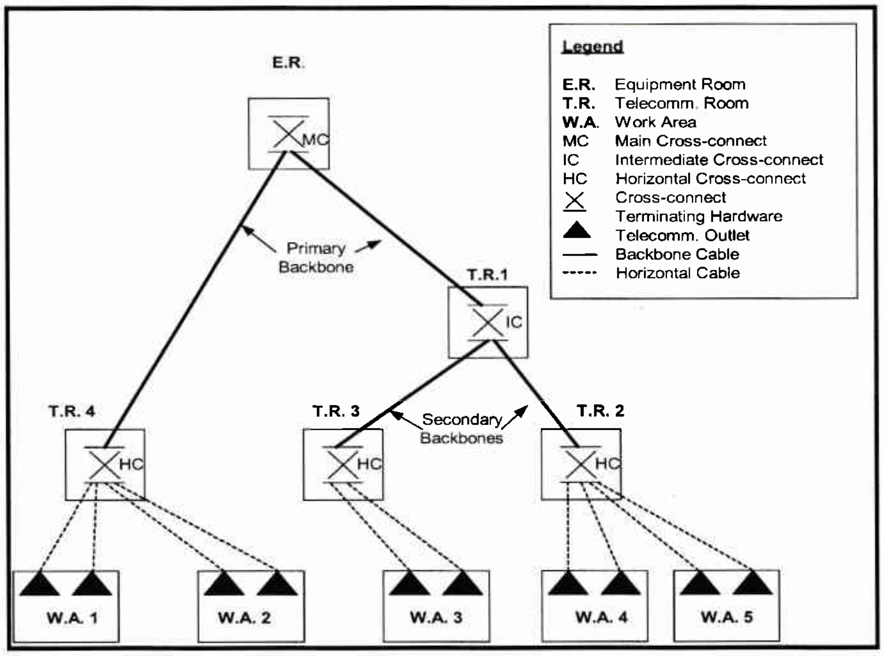
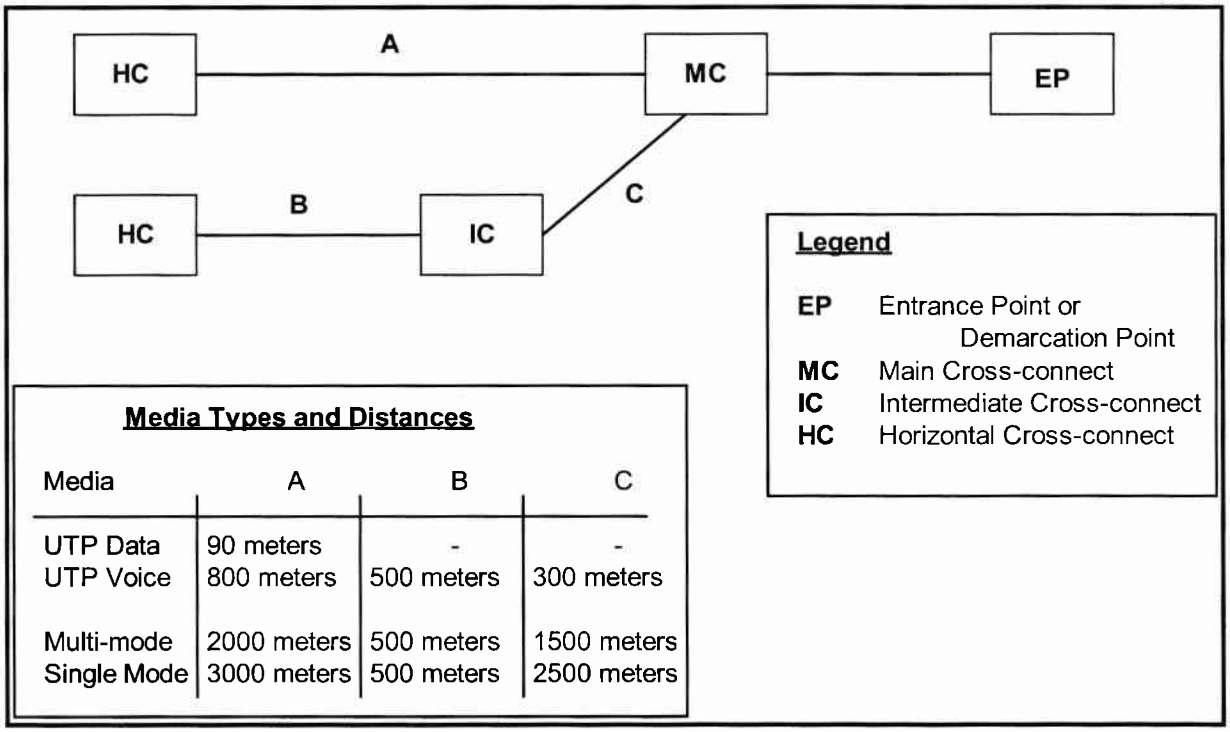


Figure 3-4 The Hierarchical Backbone Structure

- Recognized cables for Backbones are;
  - 100 UTP 4-pair or Multi-Pair (25 pair or more)
  - 62.5/125 micron or 50/125 micron Multi-mode optical fibers
- Single-mode optical fibers
- Backbone cables should be sized to meet current and short-term future requirements
- Backbone cables may be installed in phases as required
- When different backbone media are used, the media shall share the same topology and physical locations
- Maximum Backbone length are application and media dependent
  - All Category 3 or Category 5e cables for data are 90 meters maximum
  - A 5 meter cord for interconnection is permitted at each end of the Backbone
  - Category 3 or 5e cables used for voice service are 800 meters maximum
  - 62.5/125 micron multi-mode optical fiber cables are 2000 meters maximum
  - Single-mode optical fiber cables are 3000 meters maximum (Figure 3-5)
- The distance between the E/F and the Main cross-connect shall be included in the distance measurements when required by regulatory policies
- Cross-connect jumpers and patch cords shall not exceed 20 meters at either the Main cross-connect or at the Intermediate cross-connect
- Grounding and Bonding requirements shall meet TIA/EIA 607 standard



Media	A	B	C
UTP Data	90 meters	-	-
UTP Voice	800 meters	500 meters	300 meters
Multi-mode	2000 meters	500 meters	1500 meters
Single Mode	3000 meters	500 meters	2500 meters

Figure 3-5 Backbone Media Maximum Lengths

3) Work Area

- Location of the user, measuring 10 square meters or 100 square feet
- Requires two telecommunications outlets
  One category 3 or better metallic cable (normally for voice service)
  One category 5e or better, which may be two multimode optical fibers (normally for LAN)
- All 4 pairs of the horizontal metallic cable shall be terminated at the modular outlets

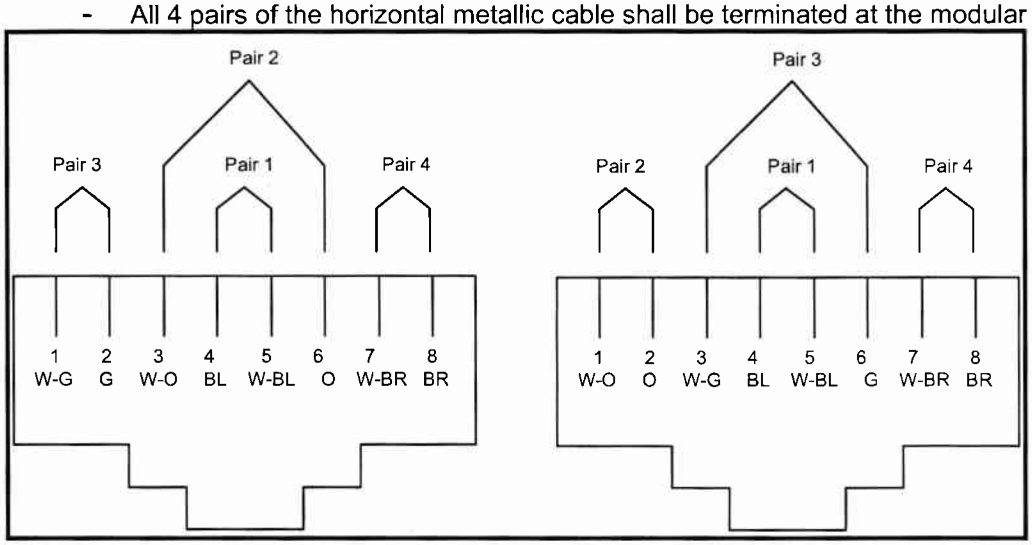


Figure 3-6 T568A and T568B T/O Configurations

- Outlets supporting copper conductors shall be configured as T568A or T568B outlets (Figure 3-6)
- All outlets shall be 8 position, 8 conductor Insulation Displacement Connectors
  Optical fiber T/O shall be a duplexed 568SC connector. Other outlet types may be considered
- A Work Area cord connecting the T/O to work area equipment;
  Shall be 5 meters or less when no MUTOA is present
  Shall be equipped with identical connectors on both ends except where an application specific device is required.
- Work area and Equipment cordage ("Patch Cords") shall be factory built off stranded copper conductors at, or above the Category rating of the Channel
- Application-specific devices, (e.g. "Y" adapters, Baluns, pair transposition etc.) shall be external to the Permanent Link, that is, must be external to the Outlet.

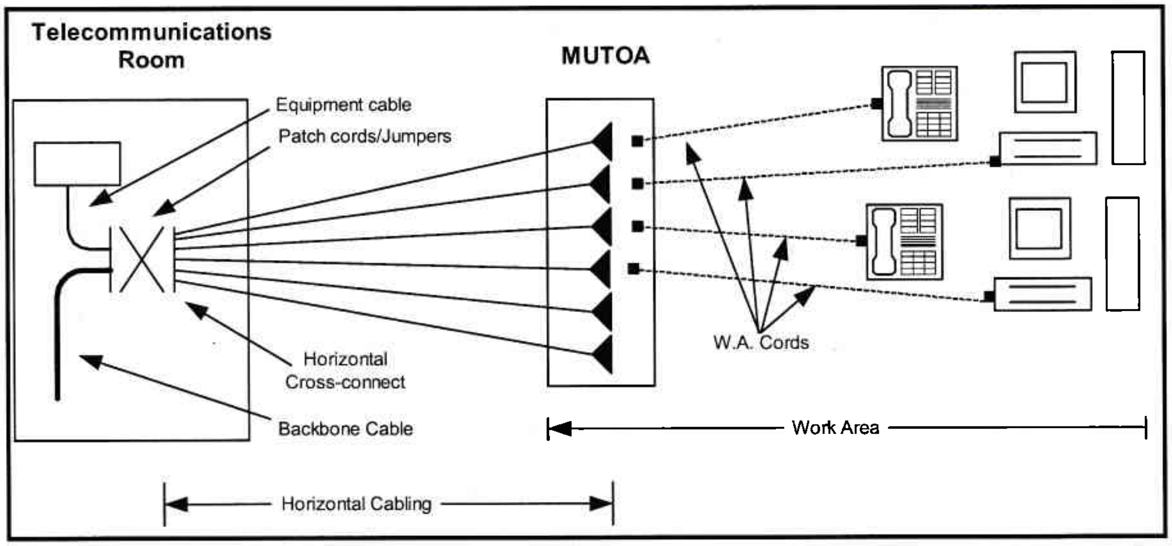


Figure 3-7 Implementation of a Multi-User Telecommunication Outlet Assembly

- Open Office cabling permits the use of a:
  A Multi-User T/O Assembly (MUTOA) (Figure 3-7 and 3-10) which permits a longer W/A cord (Figure 3-8) or
  A Consolidation Point (C.P., Figure 3-9 and 3-10) which facilitates cabling flexibility
- MUTOAs **shall not** extend the Channel length to more than 100 meters (i.e. they can only extend the work area cord by reducing the length of the Horizontal Cable. See Figure 3-8)
- MUTOAs and Consolidation Points **shall not** be used to reconfigure or re-map the Horizontal cable

Length of Horizontal Cables H meters (ft)	24 AWG UTP/24 AWG ScTP Patch Cords		26 AWG ScTP Patch Cords	
	Maximum length of work area cable W meters (ft)	Maximum combined length of work area cables, patch cords and equipment cable C meters (ft)	Maximum length of work area cable W meters (ft)	Maximum combined length of work area cables, patch cords and equipment cable C meters (ft)
90 (295)	5 (16)	10 (33)	4 (13)	8 (26)
85 (279)	9 (30)	14 (46)	7 (23)	11 (35)
80 (262)	13 (44)	18 (59)	11 (35)	15 (49)
75 (246)	17 (57)	22 (72)	14 (46)	18 (59)
70 (230)	22 (72)	27 (89)	17 (56)	27 (70)

Figure 3-8 Maximum W/A Cord Lengths Supported by a MUTOA

- MUTOAs and C. P.s can support a maximum of 12 work areas (i.e. 24outlets)
- MUTOAs and C. P.s must be secured to a permanent building structure in an unobstructed location.
- MUTOAs must be accessible by the user
- Consolidation Points shall not be accessible by the user
- Work Area cords in a MUTOA implementation shall be identified at the equipment end with the T/O used, and at the T/O end with the work area the cord serves
- Sample maximum lengths of copper W/A cords are given in Figure 3-8
- Maximum length of optical fibers used in a MUTOA shall not be reduced (i.e. maximum total length, including the two patch cords, shall be 100 meters)
- C. P.s shall not be located within 15 meters of the Horizontal cross-connect

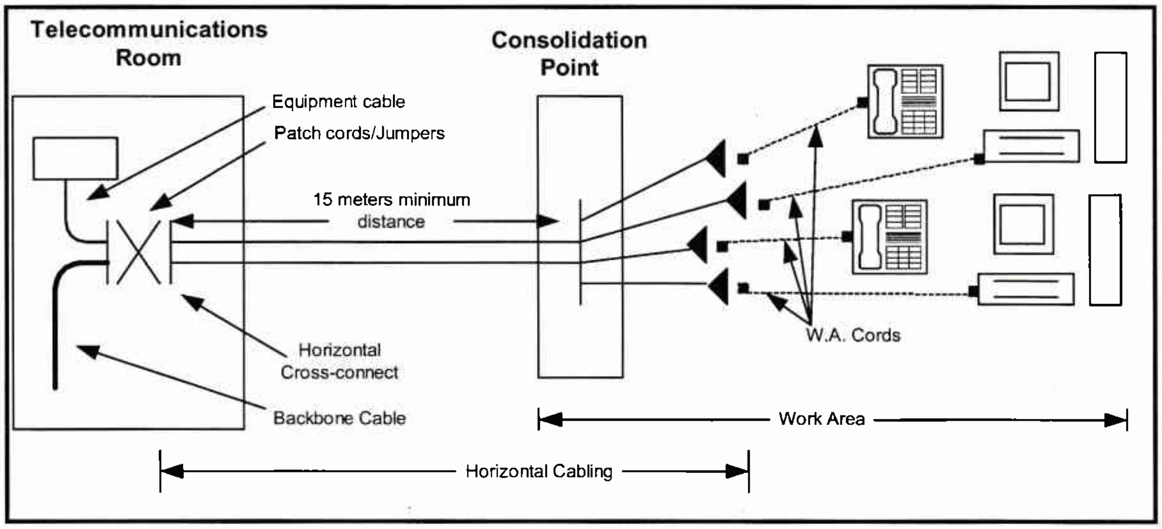


Figure 3-9 Implementation of a Consolidation Point

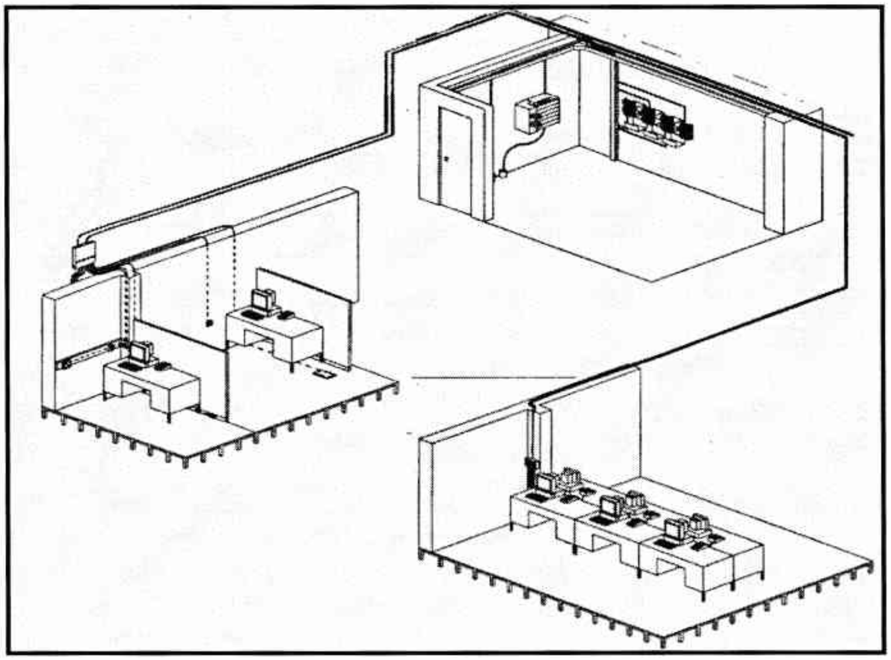


Figure 3-10 Use of the Consolidation Point and MUTOAs

4) Telecommunications Room

- The T/R shall be designed and equipped as per TIA/EIA 569-A
- The T/R provides termination of horizontal and backbone cables and their cross-connection shall use jumper cords or patch cords
- The T/R may contain an Intermediate cross-connection
- Backbone to backbone cross-connections are permitted for specific applications (e.g. Rings)
- The T/R provides a controlled environment and may house network equipment, connecting hardware, splice enclosures, demarcation points or protection.
- Equipment which consolidates several ports on a single connecter shall be terminated on dedicated hardware (i.e. a cross-connection point) (Figure 3-11)
- Equipment cords which extend a single port appearance may be either permanently terminated or interconnected to the horizontal or backbone terminations (Figure 3-11)

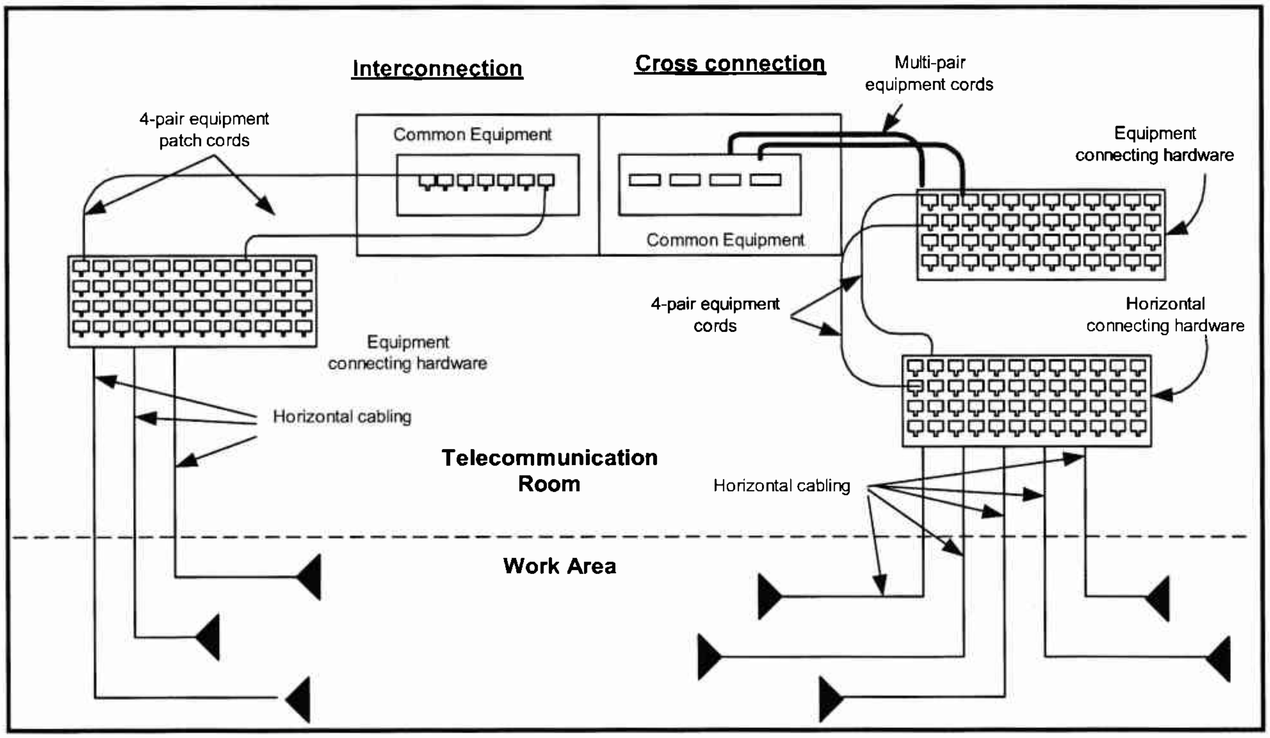


Figure 3-11 Interconnection and Cross-Connections

5) Equipment Room

- Equipment rooms are distinct from T/R due to the nature and complexity of the equipment they contain
- The PBX telephone switch and centralized optical equipment is typically located in the E/R
- An E/R may provide any or all of the functions of a T/R
- The T/R may contain the Main Cross-connect or Intermediate Cross-connect
- The E/R provides a location to cross-connect Main Backbone cables to Secondary Backbone cables
- The E/R may contain Entrance Facilities, network terminations

6) Entrance Facilities

- The Entrance Facility (E/F) consists of the cabling, terminations, demarcation points and protection devices required to connect the outside plant facilities to the premises cabling
- The E/F may be used by regulated access providers such as the telephone companies, or unregulated carriers such as private access providers.
- The Demarcation Point between the access provider and the premises cabling provider may be located in the E/F
- Electrical protection, as required by applicable electrical codes, shall be provided
- Inter-building backbones and external antennas may require grounding
- Bonding and Grounding requirements of TIA/EIA 607 shall be followed.
- Splicing between the outside plant facility and the premises facility is permitted.

7) Cabling Installation Requirements

- Cable stresses should be reduced wherever possible
- Cable ties **should not** deform the cable jacket
- Bend radius of 4-pair 100 ohm UTP cables shall not be less than 4 times the cable diameter
- Bend radius of 4-pair 100 ohm ScTP cables shall not be less than 8 times the cable diameter
- Bend radius of multi-pair cables shall not be less than 10 times the cable diameter
- All above bend radius values are under no-load (rest) conditions
- Maximum pulling tension for 4-pair UTP is 25 foot-pounds
- Maximum pulling tension for multi-pair cables shall be per manufacturers' guidelines
- Cables should be terminated on hardware of the same, or higher category as the cables
- Transmission performance of installed components shall be classified by the least performing component in the link
- The cable jacket (sheath) should only be removed as little as required for termination
- Category 5e cable pairs shall have their pair twist maintained to within 0.5 inch (13 mm) of the termination
- Category 3 cable pairs shall have their pair twist maintained to within 3 inches (75 mm) of the termination
- Patch cords shall be same category, or greater than the Horizontal cable category installed
- Patch cords should not be field terminated
- Jumper cords shall not be field made from previously jacketed cable
- 100 ohm ScTP cables shall have their drain wires bonded to the connecting hardware and grounded per TIA/EIA 607
- Minimum bend radius of 2 or 4-fiber optical cables shall be 1 inch (25 mm) under no-load conditions
- Minimum bend radius of 2 or 4-fiber optical cables shall be 2 inch (50 mm) under a maximum load of 50 foot pounds
- Minimum bend radius multi-fiber optical cables shall be per the manufacturers' guidelines
- Optic fibers shall roll their polarity on each individual link (Figure 3-12)
- Optical fiber patch cords shall consist of 2 fibers, with a polarity roll from end to end
- Optical fiber patch cords shall be terminated in 568SC connectors
- Minimum bend radius for 150 ohm STP cables shall be 3 inches (75mm)
- Maximum pull tension on STP cables shall be 55 foot pounds
- When terminating STP cables, the shield shall be terminated per manufacturers' guidelines

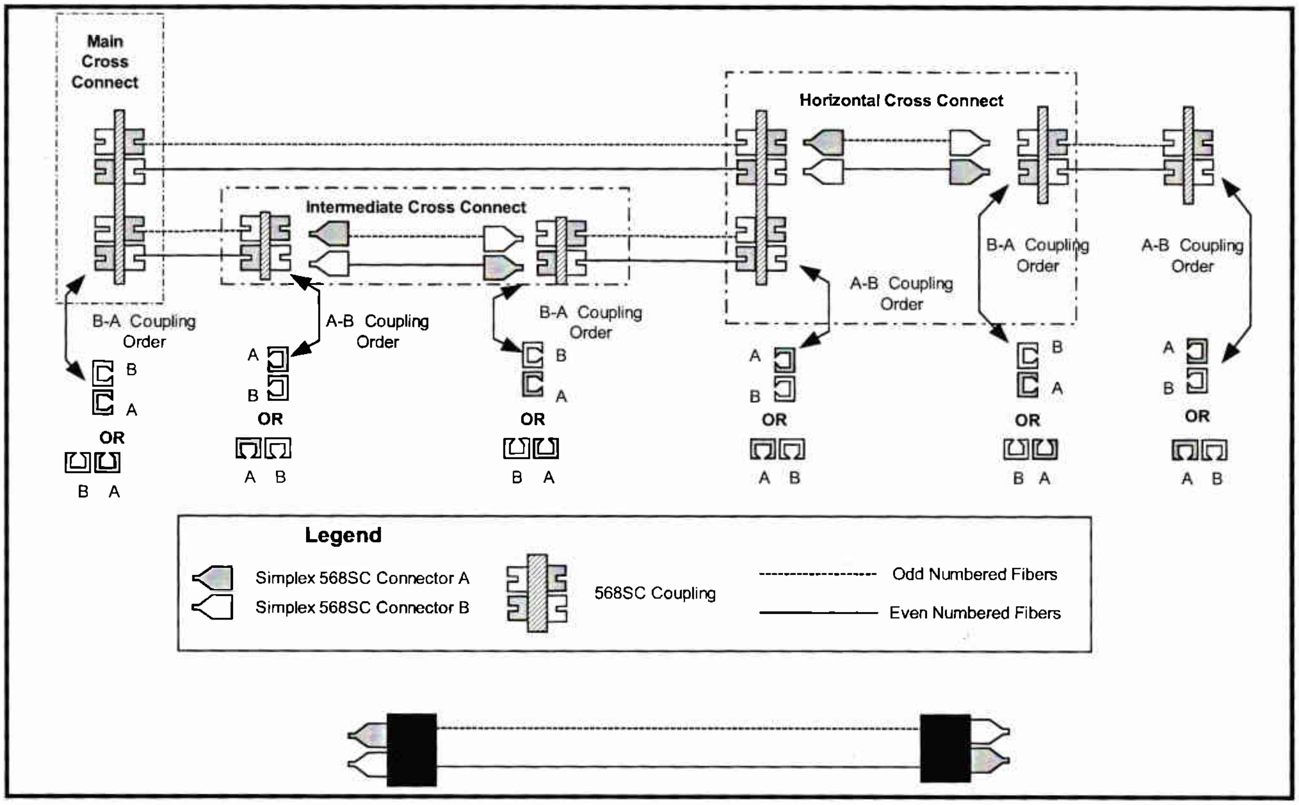


Figure 3-12 Optical Fiber Polarities for Premises Cabling

8) Cable Transmission Performance and Test Configurations

- Transmission performance depends on component characteristics, total number of connections, and the care with which the components were installed
- Post-installation "as-built" performance must be tested
- Category 3 and Category 5e structures are recognized (Cat 5 cable parameters listed in Annex D)
- Field test equipment capable of running frequency tests to 100 MHz is required
- This clause covers 100 ohm UTP and ScTP cables only
- Permitted test configurations are Channel test and Permanent Link tests
- The Channel configuration (Figure 3-13) includes;
  A maximum 5 meter W/A cord (longer cords permitted with a MUTOA)
  The Work Area Telecommunication Outlet
  A maximum of 90 meters Horizontal cable
  An optional Consolidation Point or Transition Point
  Two connections in the T/R on terminating hardware
  A maximum 5 meters of cross-connect jumper or patch cord
- The Channel test does not include the connection to equipment at either end
- The Channel test does include the user's W/A and T/R cords and jumpers

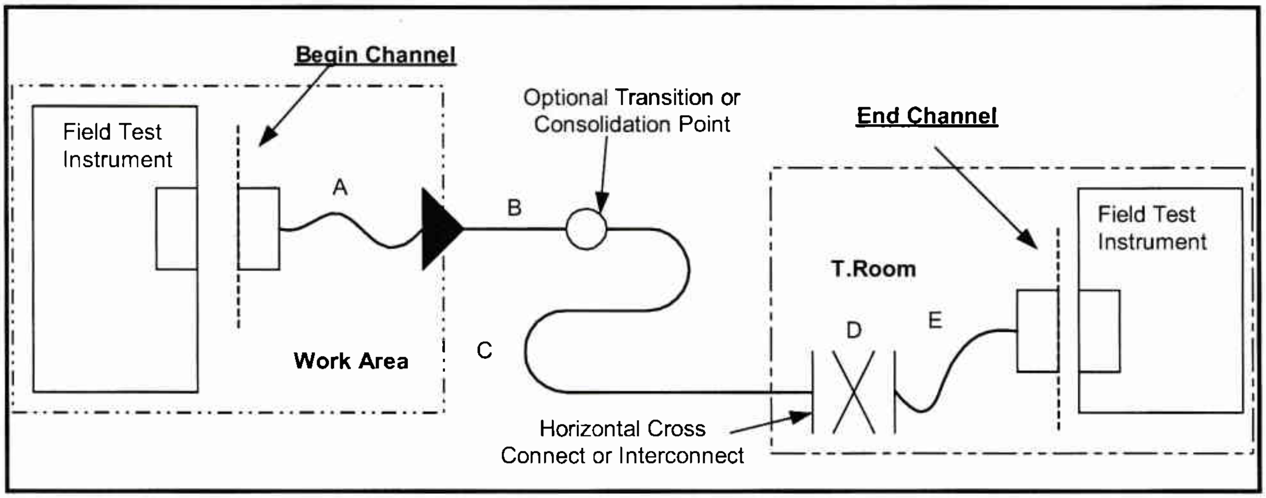


Figure 3-13 Channel Test Configuration

The Permanent Link configuration (Figure 3-14) includes:

The Work Area Telecommunications Outlet
A maximum of 90 meters of horizontal cable
The Work Area Telecommunications Outlet
An optional Consolidation or Transition Point
One connection in the T/R (the Horizontal termination hardware)

- The Permanent Link does not include any cross-connection jumpers or cords, or the Work Area cord
- Test equipment performing a Permanent Link test must "zero-out" their test cords

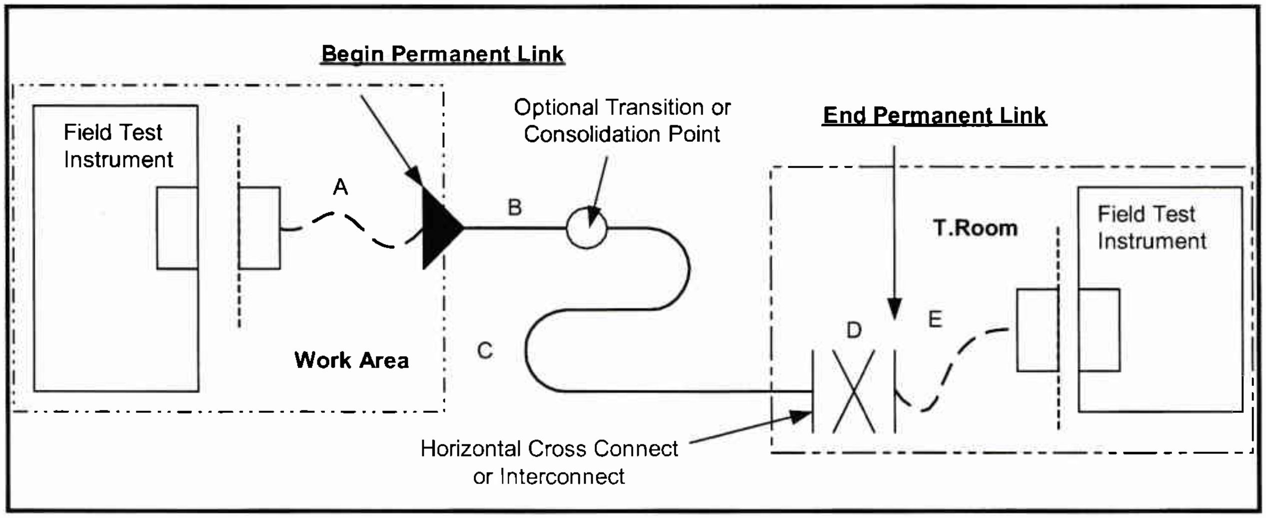


Figure 3-14 Permanent Link Test Configuration

9) Test Parameters

- The Primary field test parameters are;
  Wire Map
Length
  Insertion Loss & Return Loss
Nea r-end Crosstalk (NEXT) loss
  Power Sum Near-end Crosstalk (PSNEXT) loss
Equal-Level Far-end Crosstalk (ELFEXT) loss
Power Sum Equal-Level Far-end Crosstalk (PSELFEXT) loss
Propa gation Delay, and Delay Skew
- Category 3 cables shall be tested to 16 MHz
- Category 5e cables shall be tested to 100 MHz
- Category 6 cables are proposed to be tested to 250 MHZ (under advisement only)
- Additional parameters are under study and may be included in later editions of the document

9a) Wire Map

- Verifies the pin-to-pin termination at each end of an installed cable
- Checks for continuity and polarity of the installed cable
- See Figure 3-15a for correct map, and 3-15b-d for mapping errors

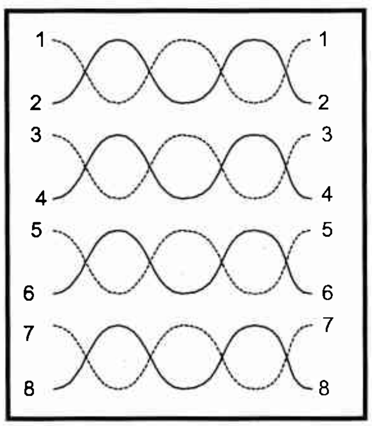


Figure 3-15a Correct map

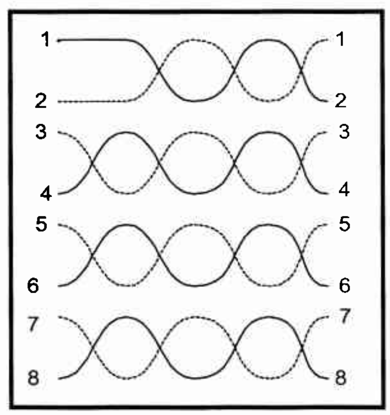


Figure 3-15b Reversed (Rolled) Conductors 1 & 2

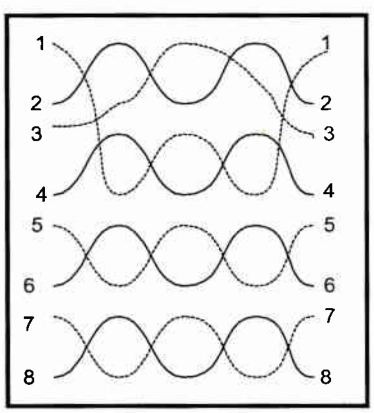


Figure 3-15c Split Pairs Conductors 1& 3, 2 & 6

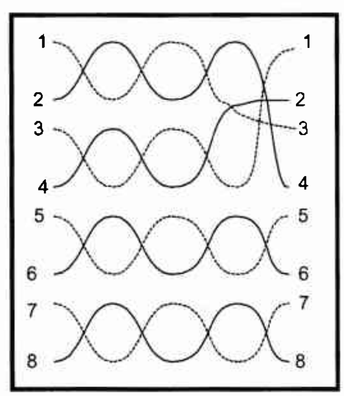


Figure 3-15d Transposed Pairs Conductors 1 & 2, 3 & 6

9b) Length

- The electrical length of the cable is greater than the physical (jacket) length
- The cable pair with the shortest electrical delay shall be reported as the length
- Electrical length requires the cables' Nominal velocity of Propagation
- A tolerance of +/- 10% in the NVP is permitted
- Maximum Permanent Link length shall be 90 meters
- Maximum Channel length shall be 100 meters

9c) Insertion Loss

- Insertion loss (attenuation) is a measure of signal loss over the Channel or Permanent Link. All losses measured at 20° C.
- Channel insertion loss is derived from;
  Insertion loss of 4 connectors
  Insertion loss of 10 meters of patch cords or jumpers
  Insertion loss of 90 meters of Horizontal cable
- Permanent Link insertion loss is derived from;
  Insertion loss of 3 connectors
  Insertion loss of 90 meters of Horizontal cable
- Insertion losses increase with frequency and with cable length

Frequency (in MHz)	Catergory 3 Losses (in dB)	Category 5e Losses (in dB)
1.0	4.2	2.2
4.0	7.3	4.5
8.0	10.2	6.3
10	11.5	7.1
16	14.9	9.1
20	-	10.2
25	-	11.4
31.25	-	12.9
62.5	-	18.6
100.0	-	24.0

Figure 3-16 Sample Values for Insertion Loss in Channel Configuration Tests

Frequency (in MHz)	Catergory 3 Losses (in dB)	Category 5e Losses (in dB)
1.0	3.5	2.1
4.0	6.2	3.9
8.0	8.9	5.5
10	9.9	6.2
16	13.0	7.9
20	-	8.9
25	-	10.0
31.25	-	11.2
62.5	-	16.2
100.0	-	21.0

Figure 3-17 Sample Values for Insertion Loss in Permanent Link Configuration Tests

9d) Pair to Pair NEXT Loss

- NEXT measures the effect of a disturbing pair on a disturbed pair within the 100 ohm UTP cable
- All pair combinations (6) are measured from both ends
  1 & 2 to 3 & 6
  1 & 2 to 4 & 5
  1 & 2 to 7 & 8
  3 & 6 to 4 & 5
  3 & 6 to 7 & 8
  4 & 5 to 7 & 8
- NEXT is measured from 1.0 MHz to the highest frequency the cable is designed to support
- NEXT is frequency sensitive, and becomes greater at higher frequencies
- NEXT value is dependent on the overall length of the cable

Frequency (in MHz)	Catergory 3 Losses (in dB)	Category 5e Losses (in dB)
1.0	39.1	>60
4.0	29.3	53.5
8.0	24.3	48.6
10	22.7	47.0
16	19.3	43.6
20	-	42.0
25	-	40.3
31.25	-	38.7
62.5	-	33.6
100.0	-	30.1

Figure 3-18 Sample NEXT Losses for a Channel

Frequency (in MHz)	Catergory 3 Losses (in dB)	Category 5e Losses (in dB)
1.0	40.1	>60
4.0	30.7	54.8
8.0	25.9	50.0
10	24.3	48.5
16	21.0	45.2
20	-	43.7
25	-	42.1
31.25	-	40.5
62.5	-	35.7
100.0	-	32.3

Figure 3-19 Sample NEXT Losses for a Permanent Link

9e) Power Sum NEXT loss

- A calculation of the combined crosstalk on a receive pair from all near-end disturbers
- PSNEXT tests are **not** required on Category 3 cables
- PSNEXT is calculated for all 12 combinations at each end of a 4-pair cable (24 tests in total).
- Mathematically, the PSNEXT is calculated;

PSNEXT $_a$ (dB) = -10 log (b + c+ d)

Where b, c, & d are the NEXT values (as a ratio) for the three disturbing pairs, b, c, & d.

- Category 5e channel PSNEXT;
  - At 1 MHz less than 57 dB
  - At 100 MHz less than 27.1 dB
- Category 5e permanent link PSNEXT
  - At 1 MHZ less than 57 dB
  - At 100 MHz less than 29.3 dB

9f) FEXT and ELFEXT

- FEXT is a measure of signal coupling from a transmitter at the near-end of the cable, to another pair at the far-end
- 12 measurements are taken from each end of the cable (24 in total)
- Pair-to-pair ELFEXT is the difference between the measured FEXT loss and the insertion loss on the disturbed pair
- Twenty-four ELFEXT values are calculated on a single 4-pair cable
- ELFEXT tests are **not** required on Category 3 cables.
- Category 5e channel ELFEXT;
  - At 1 MHz less than 57.4 dB
  - At 100 MHz less than 17.4 dB
- Category 5e permanent link ELFEXT
  - At 1 MHz less than 58.6 dB
  - At 100 MHz less than 18.6 dB

9g) PSELFEXT

- PSELFEXT is a calculation of the combined effect of the disturbing pairs on a disturbed pair
- It is **not** a required test for Category 3 cables.
- Category 5e channel PSELFEXT;
  - At 1 MHz less than 54.4 dB
  - At 100 MHz less than 14.4 db
- Category 5e permanent link PSELFEXT;
  - At 1 MHz less than 55.6 dB
  - At 100 MHz less than 15.6 dB

9h) Cabling Return Loss

- A measurement of the reflected energy returned to the transmitter, caused by impedance variations in the cable and connectors
- Return Loss tests are not required for Category 3 cables.
- Category 5e channel Return Loss;
  At 1 MHz less than 17 dB
  At 100 MHZ less than 10 dB
- Category 5e permanent link Return Loss;
  At 1 MHz less than 19 dB
  At 100 MHz less than 12 dB

9i) Propagation Delay

- The time it takes for an electrical signal to propagate from one end of the cable to another
- For all categories of cables, Propagation delay shall not exceed
  555 nano-seconds at 10 MHz for a channel configuration
  498 nano-seconds at 10 MHz for a permanent link configuration

9j) Delay Skew

- The propagation difference between pairs in a single cable
- Delay skew for all categories shall not exceed 50 nano-seconds in a channel configuration, or exceed 44 nano-seconds in a permanent link configuration.

10) Optical fiber transmission performance and test requirements

- Link Segment definition:
  The cable, connectors and splices between 2 connecting hardware points.
- Horizontal link segment definition:
  Horizontal cable, the T/O and horizontal cross-connect.
- Backbone link segment definition:
  Main cross-connect to Horizontal cross-connect, or
  Main cross-connect to Intermediate cross connect, or
  Intermediate cross connect to horizontal cross-connect.
- Centralized optical fiber segment definition:
  T/O, cable to centralized cross-connect, and a splice or interconnect point in the Telecommunications Room
- Fiber Optic Losses:
  Loss across a mated pair of conductors shall be less than 0.75 dB per mated pair
  Loss across a splice shall be less than 0.3 dB
  Loss on 62.5/125 or 50/125 Fiber optic cable at 850 nano-meters shall be 3.5 dB per km
  Loss on 62.5/125 or 50/125 Fiber optic cable at 1300 nano-meters shall be 1.5 dB per km
  Loss on interior Single-mode Fiber optic cable shall be 1.0 dB per km
  Loss on exterior Single-mode Fiber optic cable shall be 0.5 dB per km

D: TIA/EIA 568-B.3

TIA/EIA-568-B.3

Optical Fiber Cabling Components Standards

Clause 1 Introduction

- Standardizes the requirements for transmission and components of a fiber optic cable system.
- Only 50/125, 62.5/125 multimode and single-mode optical fibers are recognized
- Mandatory criteria are designated by the word "shall"
- Advisory criteria are designated by the words, "should", "may" or "desirable"
- This is a living document, and is subject to revision and updates

Clause 2 Scope

- Minimum requirements are stated
- Normative references include the TIA/EIA 568-B Parts 1 and 2, TIA/EIA 606, TIA/EIA 607 and other documents

Clause 3 Definitions, Abbreviations and Acronyms, Units of Measure

- See Glossary at end of summaries

Clause 4 Optical Fiber Cables

- Outside cable plant optical fibers shall comply with ANSI/ICEA S-87-640.
- Inside cable plant optical fibers shall comply with ANSI/ICEA S-83-596
- Attenuation losses shall meet the requirements of Table 1
- Optical fiber cables shall consist of 50/125, 62.5/125 or single-mode fibers or a combination of fiber types
- Individual fibers shall be identifiable
- Optical fiber cables shall be listed and marked as required by electrical and building codes
- 2 and 4 fiber Horizontal or Centralized optical cables shall support a bend radius of 25 mm (1 inch) under no-load
- 2 and 4 fiber cables intended for pulling through pathways shall support a bend radius of 50 mm (2 inches) under a pull load of 50 foot-pounds
- All other multi-pair cables shall support a bend radius of 10 times the cable diameter, under the cable's specified tensile load
- Outside cables shall be of a water block construction and have a minimum pull strength of 600 foot-pounds
- Outside cables shall support a bend radius of 10 times the cable diameter under no-load, and 20 times the cable diameter under rated load

- Work Area cables shall have a minimum pull strength of 300 lbf

Optical Fiber Cable Type	Wavelength (nm)	Maximum Attenuation (Db/km)	Maximum Information Transmission Capacity for Overfilled Launch (MHZ*km)
50/125 um Multimode	850	3.5	500
	1300	1.5	500
62.5/125 um Multimode	850	3.5	160
	1300	1.5	500
Singlemode Inside Cable	1310	1.0	N/A
	1550	1.0	N/A
Singlemode Outside Cable	1310	0.5	N/A
	1550	0.5	N/A

Table 3-20: Attenuation Specifications for Recognized Fiber Optic Cables

Clause 5 Connecting Hardware

General

- Covers performance specifications for optical fiber connectors, connecting hardware and splices
- Connection hardware apply to the main cross-connect, intermediate cross-connect, horizontal cross-connect, centralized cabling interconnection and splice, consolidation point and work area

Connector and Adapter

- Various connector designs are permitted, provided the connectors meet the requirements of Annex A, and the Fiber Optic Connector Intermateability Standard (FOCIS)
- The duplex 568SC connector and adapter is used for reference
- Connectors shall meet ANSI/TIA/EIA-604-3 and FOCIS requirements
- No provision is made to prevent single-mode and multimode mating
- Multimode connectors and outlets shall be coloured beige
- Single-mode connectors and outlets shall be coloured blue
- The duplex SC568 connector and adapter shall be referred to as Position A and Position B. See Figure 3-21 and Figure 3-22 for keys and keyways
- A 568SC adapter shall perform a pair-wise cross over between connectors

- Alternate connector designs shall use the same scheme for label and identification purpose
- For designs using latches, the latch shall define the same position as the keys in Figure 1 & 2

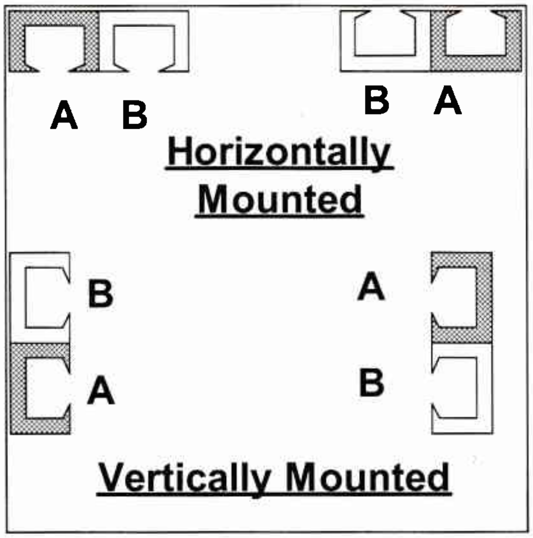


Figure 3-21 A & B Adapter

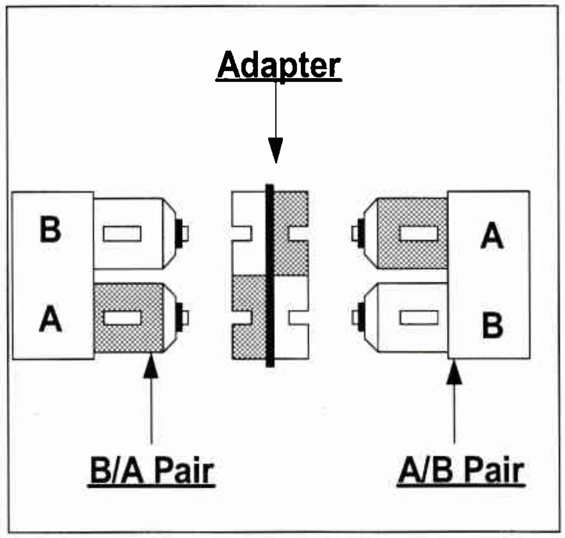


Figure 3-22 Duplex 568SC Connectors and Adapter

<u>Telecommunications Outlets</u>

- Telecommunication outlets shall be able to terminate 2 optical fibers as a minimum
- The outlet shall be able to secure the fiber and to maintain a minimum bend radius of 25 mm

<u>Patch Panels</u>

- Connecting hardware should provide for flexible mounting on walls, in racks, or on distribution frames
- Connecting hardware should provide for high-density terminations
- An optical fiber patch panel shall provide;
  A means of cross connecting with patch cords
  A means of interconnecting premises equipment to the optical cables
  A means of identifying the cables and the termination field groups for
admini stration purposes (TIA/EIA-606)
  A means of promoting orderly cable management
  A method of access for monitoring and testing the signals
  Adequate protection for connections and adapters on the cabling side to prevent contact with foreign objects that could degrade the
perfo rmance

Hardware for Centralized Cabling

- Hardware designed to connect horizontal cables to intra-building backbones in a centralized optical cabling environment shall be designed to;
  Provide a means of joining cables using either re-mateable connectors or splices. Only one type should be used.
- Connectors must meet other requirements of this standard. Splices may be mechanical or fusion, and meet other requirements of this standard
- Provide a means of organizing the fibers in pairs
- Provide a unique identifier for each connector
- Permit the removal of existing connections and adding additional c onnectors
- Provide a means of storing and identifying non-connected fibers
- Provide accommodation for additional horizontal or backbone cables
- Permit a migration from an interconnect or splice to a cross connection
- Permit access for testing the optical fiber
- Provide protection for connections against contact with foreign object
- The manufacturer shall provide instructions and recommendations to accomplish the above

Optical Fiber Splices

- A fusion or a mechanical optical fiber splice shall not exceed 0.3 dB loss
- Optical fiber splices shall have a minimum return loss of 20dB for multimode or 26 dB for single-mode
- Minimum return loss for single-mode used in an analog video (CATV) application shall be 55 dB

Clause 6 Patch Cords

General

- Optical fiber patch cords are designed to connect optical fibers at cross-connection points, and as work area or equipment cords
- An optical fiber patch cord shall have two fibers, of the same type as the horizontal and backbone fibers
- The patch cord shall be of indoor construction, and meet the requirements of other sections of this standard
- Patch cord connectors shall meet the requirements of other sections of this standard
- Patch cords shall be oriented so that a pair reversal will occur. See Figure 3-23

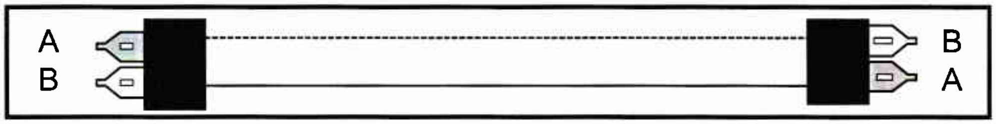


Figure 3-23 Optical Fiber Patch Cord with Pair Reversal

- In simplex connectors the receiver connector shall be considered Position A, and the connector that plugs into the transmitter shall be considered Position B
- In connectors using a latch system instead of keys, the latch shall determine the pair configuration in the same way the key does

Clause 7 Field Test Instruments

Multimode

- Multimode field test instruments shall meet the requirements of ANSI/TIA/EIA-5236-14-A
- The light source shall meet Equilibrium Distribution Mode requirements, by use of an external mandrel (see TIA/EIA-568-B.1) or an internal light stripper in the source

Single-mode

- Single-mode field test instruments shall meet the requirements of ANSI/TIA/EIA-526-7

Annex A Optical Fiber Connector Performance Specifications (Normative)

Annex B Bibliography and References

E) Colour code for 25-Pair Metallic Cables

Electricity requires two conductors in order to flow between two points. The terms Tip and Ring come from the telephone world, and are still used to identify the conductors in a pair. The 10 colours used permit easy identification of 25 pairs by using all combinations possible. The first pair is the Blue/White pair, with the Tip = White/Blue and Ring = Blue/White etc.

A 4-pair cable only uses the first four ring colours, along with the tip "family" colour of white.

Pair 1	White/Blue (tip)	Blue/White (ring)
Pair 2	White/Orange (tip)	Orange/White (ring)
Pair 3	White/Green (tip)	Green/White (ring)
Pair 4	White/Brown (tip)	Brown/White (ring)

Colour Code for S.C.S.

Ring Colours

Tip Colours	Blue	Orange	Green	Brown	Slate
White	1	2	3	4	5
Red	6	7	8	9	10
Black	11	12	13	14	15
Yellow	16	17	18	19	20
Violet	21	22	23	24	25

Figure 3-24 Colour Code Used in S.C.S. Cables

F) Colour code for Fiber Optic Cables

Fiber Optic strands do not carry current, and therefore do not require a return conductor. As only one fiber optic conductor is required to connect a transmitter to a receiver, fiber optic strands are colour-coded individually. The colour code is the same as that used in metallic cables, but with the inclusion of an eleventh and twelfth strand. The colour code for Optical Fibers is:

Fiber 1	Blue	Fiber	2	Orange
Fiber 3	Green	Fiber	4	Brown
Fiber 5	Slate	Fiber	6	White
Fiber 7	Red	Fiber	8	Black
Fiber 9	Yellow	Fiber	10	Violet
Fiber 11	Rose (Pink)	Fiber		Aqua (light Blue)

Rather than placing the optical fiber strands in a binder, each group of 12 strands may be placed in a loose tube buffer, baring the same colour code. The first tube will be Blue, the 12th will be Aqua. In multiple strand optical cables, either the buffer (the 250 micron buffer coat) or the 900 micron tight buffer will display the distinctive colour. Groups of 12 fibers will be treated as a binder group.

G) Summary of TIA/EIA 568B Document.

This document is the key to the correct installation of a Structured Cable System, and it details, in some minutia, the installation of the cables. The following summary is provided to the student for reference only. For complete details, the full document should be consulted.

- Physical topology of the Horizontal cabling shall be a Star ("Home Run")
- Maximum length from T/O to terminating hardware shall be 90 meters
- Recognized copper cables are 4-pair 100 ohm Unshielded Twisted Pair (UTP)
- Each Work Area shall have two Telecommunication Outlets.
- These two Outlets shall support:
  One Category 3 or better cable, and be metallic, and
  One Category 5e or better cable, which may be Multi-mode Optical Fiber
- Recognized optical fibers for Horizontal cables are 2 fibers of 62.5/125 micron or 50/125 micron Multi-mode cable
- All 4 pairs of the horizontal metallic cable shall be terminated at the modular outlets
- Bridge taps, splices or splitters shall not be permitted on Horizontal cables
- Recognized cables for Backbones are;
  100 UTP 4-pair or Multi-Pair (25 pair or more)
  62.5/125 micron or 50/125 micron Multi-mode optical fibers
- Coaxial cables are no longer supported by the standard
- Horizontal cables shall be certified as Permanent Links

Section 3 Summary

The Standards

The ISO 11801 Standard
The Four North American Standards

TIA/EIA 568B: Commercial Building Telecommunication Cabling Standard

Horizontal Cables:
- Physical Star, 90 meters Permanent Link, T.O to Termination
- 100 Ohm UTP 4-pair category cables,
- Multi-mode Fiber Optics with T568SC Connectors
- No Bridge Taps, Splices or Splitters on Horizontal Cables

Backbone Cables:
Hierarchical Star Topology
- 100 Ohm UTP 4 pair, 25 pair or more Category Cables
- Single or Multi-mode Fiber Optics
- Connect Telecomm Rooms to the Equipment Room

Work Area:
- User Location, 10 square meters per User
- Two Outlets per W.A, 1 Category 3 or better & Metallic
  1 Category 5e or better & may be Fiber Optic
- T568A or T568B outlets, all 4 pairs connected for Metallic
- Outlets must be Insulation Displacement Connectors
- W.A Cords 5 meters maximum length without MUTOA
- W.A Cords shall be Factory Built of Stranded Category cables
- All Equipment Adapters must be External to the Permanent Link
- MUTOA and Consolidation Points as described
- MUTOA does not permit Channels over 100 meters
- MUTOA and CP not to be used to re-configure the Permanent Link

Telecommunications Room:
- At least one per floor, more if floor size requires it
- Center of Star Topology for Horizontal Cables
- Provides a point to Cross-connect the Horizontal and Backbone
- May contain some active devices
- Equipment cords shall be factory built to Category level

Equipment Room:
- Contains major active equipment such as PBX, Hubs, Switches, and Routers
- May have a Telecomm Room or Entrance Facility co-located
- Have Backbone cables to each Telecomm Room
- Connects to the Entrance Facility
- Location of Telecommunication Main Grounding Bus-bar
- May have Centralized Fiber Optic Equipment

Entrance Facilities:
- Location where Outside Facilities appear in the Building
- Demarcation Points and Lightning Protection
- Bonding and Grounding area

Cable Installation:
- Bend Radius of Cables
- Pulling tension 25 pounds for 4-pair
- Untwist pairs no more than:
  - 1/2 inches for Category 5e and above
  - 3 inches for Category 3
- Cable Performance decided by lowest Category in the Channel
- Metallic Pairs shall Maintain Polarity on the Permanent Link
- Optical fibers shall Reverse Polarity on the Permanent Link
- Patch Cords shall be Factory built

Colour Code
- Metallic Pairs
- Fiber Optic Strands

Test Parameters
- Cable Mapping
- Length
- Insertion Loss (Attenuation)
- Bi-directional Near End Cross-Talk (NEXT)
- Power Sum NEXT
- Far End Cross Talk (FEXT)
- Equal Level FEXT
- Power SUM ELFEXT
- Return Loss
- Propagation Delay and Delay Skew
  - Optical Fiber losses

Section 4 TIA/EIA 569, 606 and 607 Documents

A: TIA/EIA-569-A and CAN/CSA-T530-M90

Building Facilities, Design Guidelines for Telecommunications

The following is a summary of the TIA/EIA-607 Commercial Building Grounding and Bonding Requirements for Telecommunications document, and as such is subject to errors of omission and interpretation. Where accuracy and completeness is required, refer to the original document.

Clause 1 Introduction

- A living document, subject to future revisions and updating
- Addresses the fact that buildings often undergo renovations
- Recognizes that telecommunication systems are dynamic, and that telecommunications is more than just voice and data
- It is necessary to include telecommunications requirements in the design and construction of a building
- The purpose of this document is to standardize commercial building spaces and pathways in support of the TIA/EIA-568-B standard
- Goal of standard is to provide a non-vendor specific, non-application specific infrastructure that will prove to be useful to owners and tenants
- No specific recommendations among design alternatives (e.g. conduit or ladder tray) is given

Clause 2 Scope

General

- Limited to the telecommunication requirements of commercial buildings
- Only pathways and spaces are standardized, **not** the media or equipment
- Does **not** cover any safety issues of building construction
- Both single and multiple tenant buildings are recognized

Basic Building Elements (Figure 4-1)

- Design life of a building is many decades, and the spaces and pathways must be designed to avoid obsolescence
- Horizontal Pathways provide pathways from the work areas to the horizontal termination points
- Intrabuilding Backbone Pathways provide pathways between the Telecommunications Rooms and the Equipment Room, and between Telecommunications Rooms (Tie Pathways)
- Work Areas are locations where the user, terminal equipment and telecommunications outlets exist
- Telecommunications Rooms are floor-serving spaces for terminating horizontal cables, cross-connections, and some equipment. Transition point between backbone and horizontal cables
- Equipment Rooms serve to house larger telecommunications equipment, and are often special purpose rooms. Equipment rooms require a connection to the Entrance Facility
- Entrance Facilities are locations where outside plant cables enter the building, including;

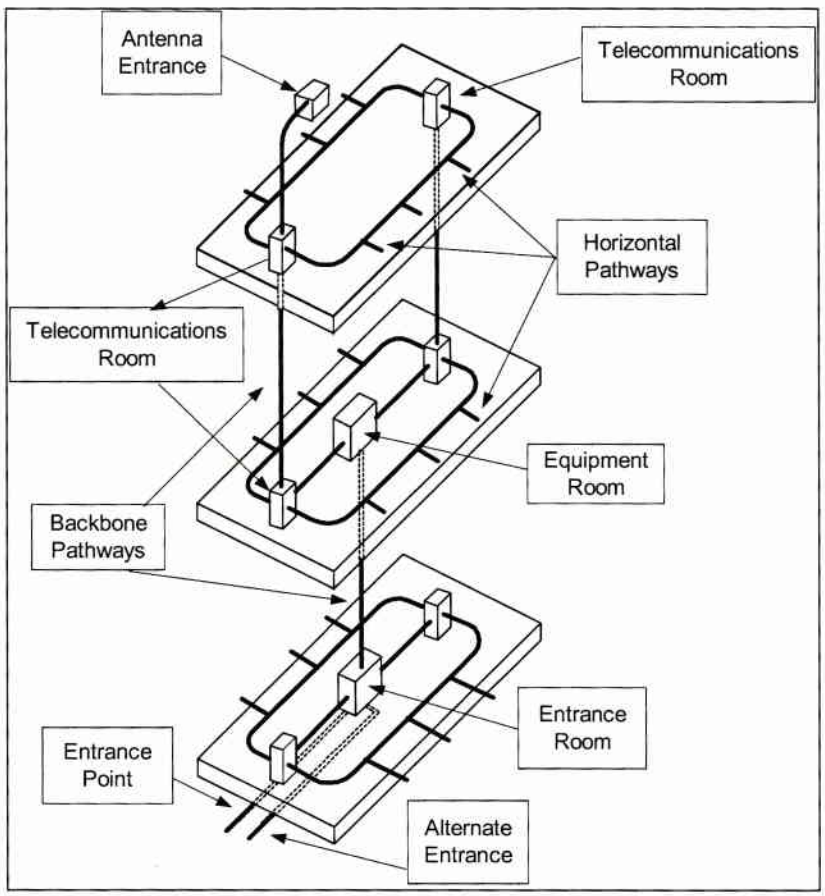


Figure 4-1 Intrabuilding Pathways

Clause 4 Horizontal Pathways and Related Spaces

General

- Horizontal pathways provide a facility for the installation of horizontal cables and may include;
- Bonding and grounding of pathways is covered by TIA/EIA-607 and local electrical codes
- Pathways shall be capable of carrying all media recognized in TIA/EIA-568-B
- Pathways shall be sized for quantity and size of cables, bend radius and future growth
- Horizontal pathways shall **not** be located in elevator shafts

Types of Pathways

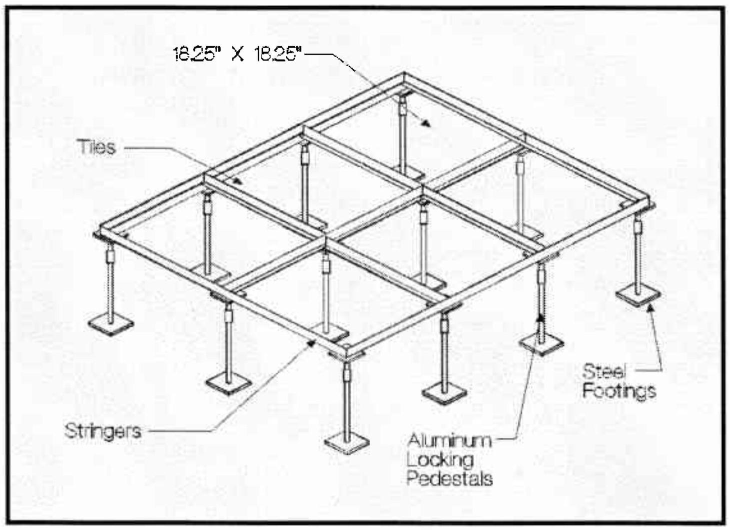


Figure 4-2 Raised or Access Floor Pathways

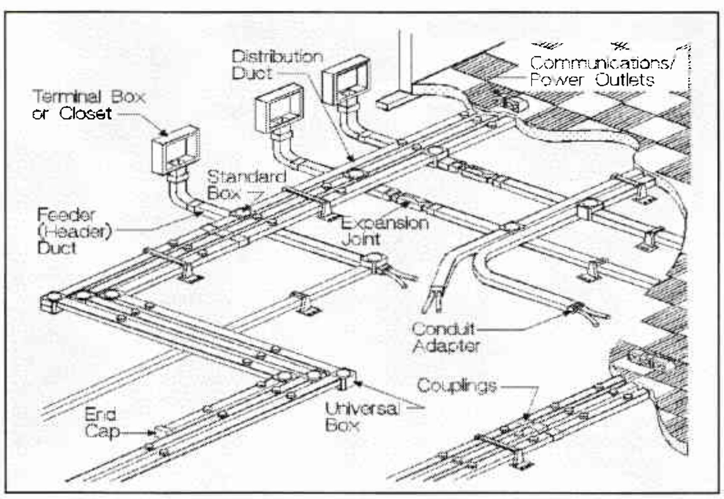


Figure 4-3 Under-floor Ducts in Concrete

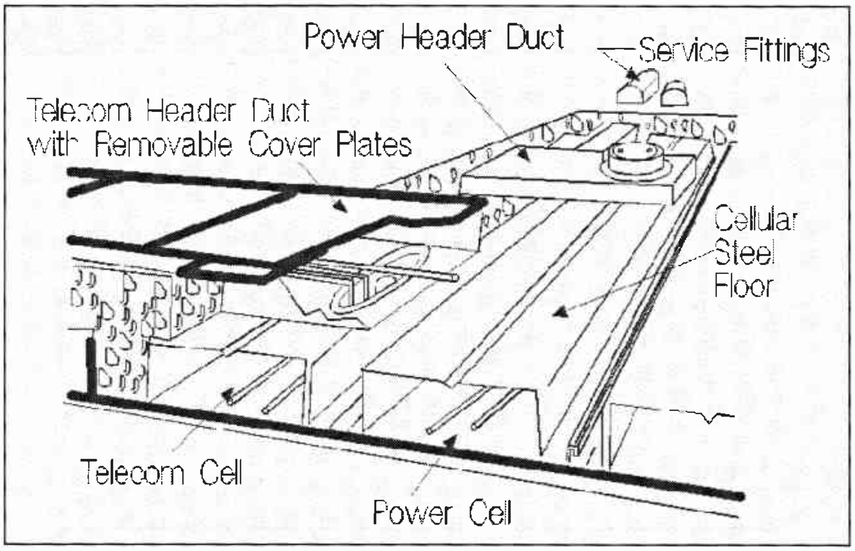


Figure 4-4 Cellular Floor in Concrete

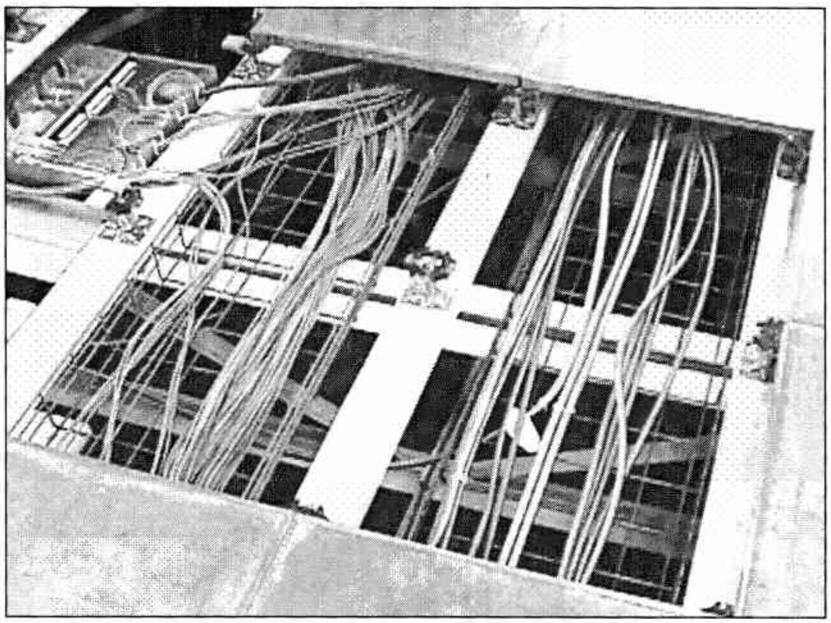


Figure 4-5 Access Floor

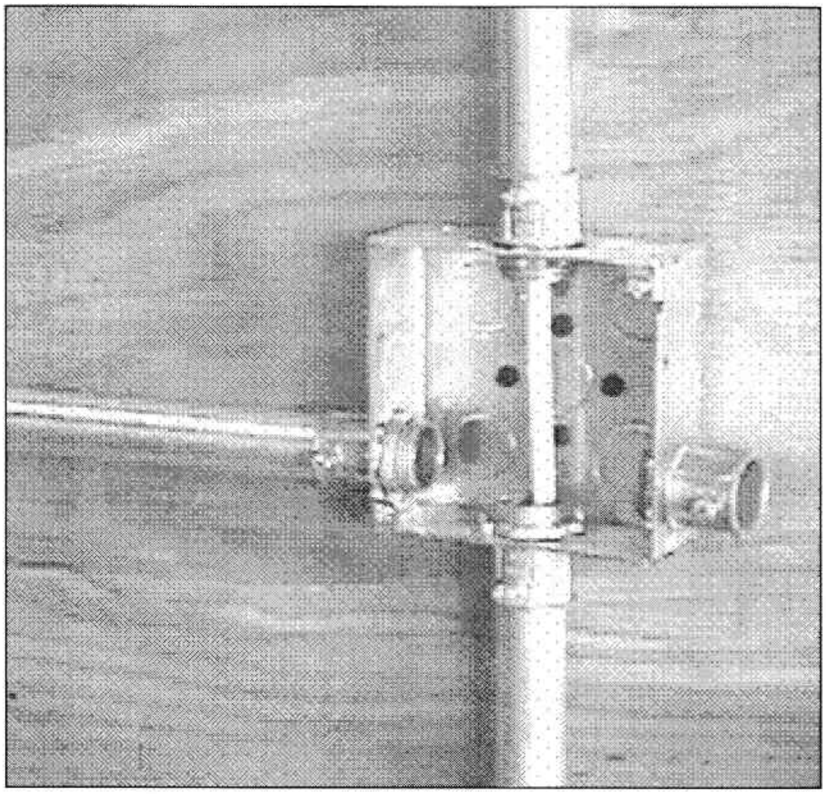


Figure 4-6 Conduit and a Pull Box

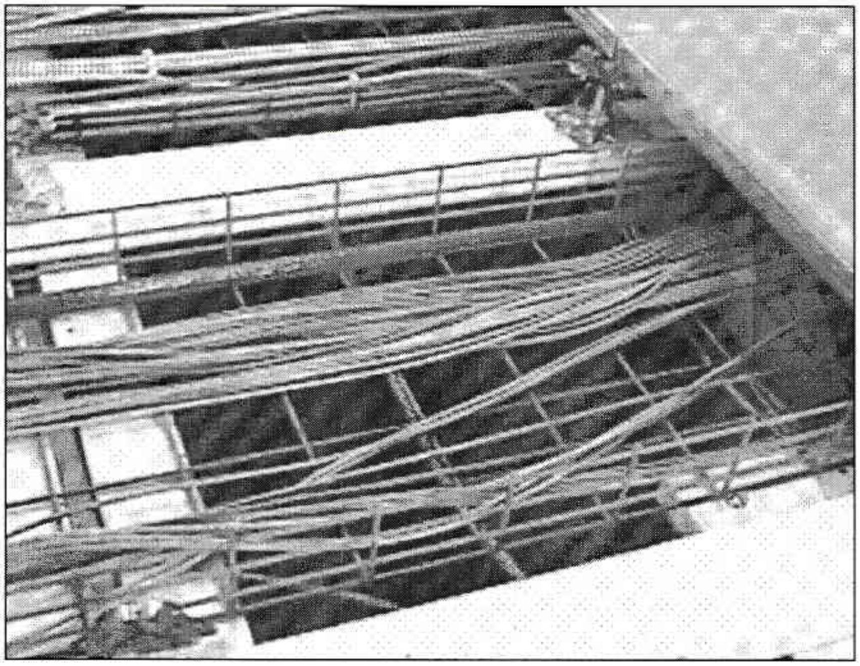


Figure 4-7 Cable Tray or Wire Trays in Sub-floor

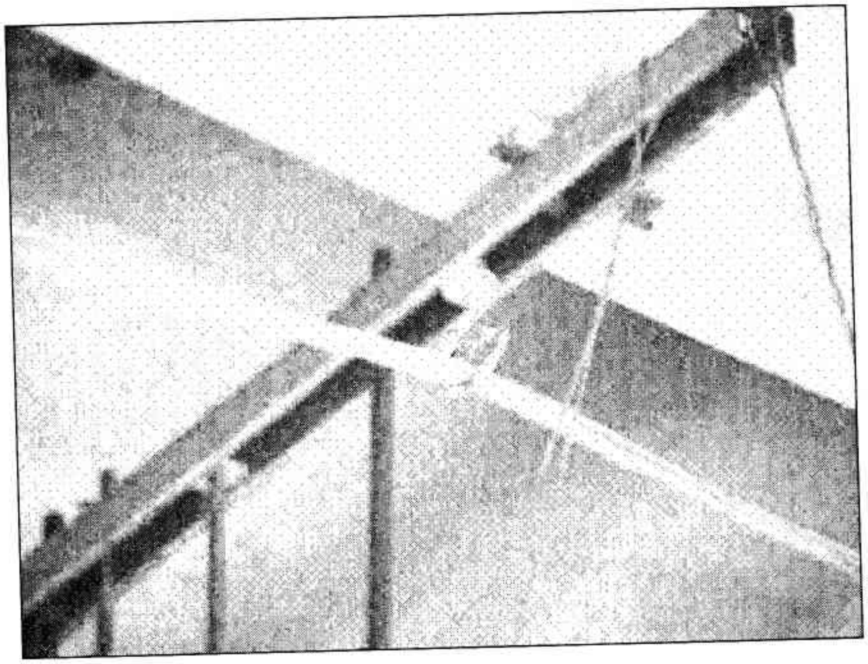


Figure 4-8 Ceiling Pathway

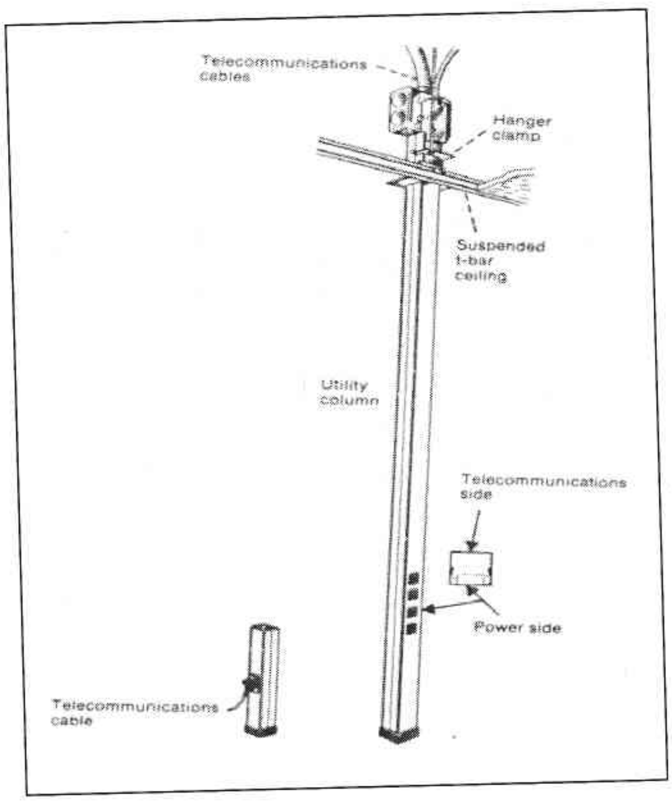


Figure 4-9 Utility Column

Pathway Requirements

- Trays and Zone conduits shall extend 25-75 mm into the TR before any bends, and above 2.4 meters
- When using removable partitions as pathways, a snap-in panel or cover shall be provided
- Hollow walls may be used as a pathway if an accessible space or conduit is provided

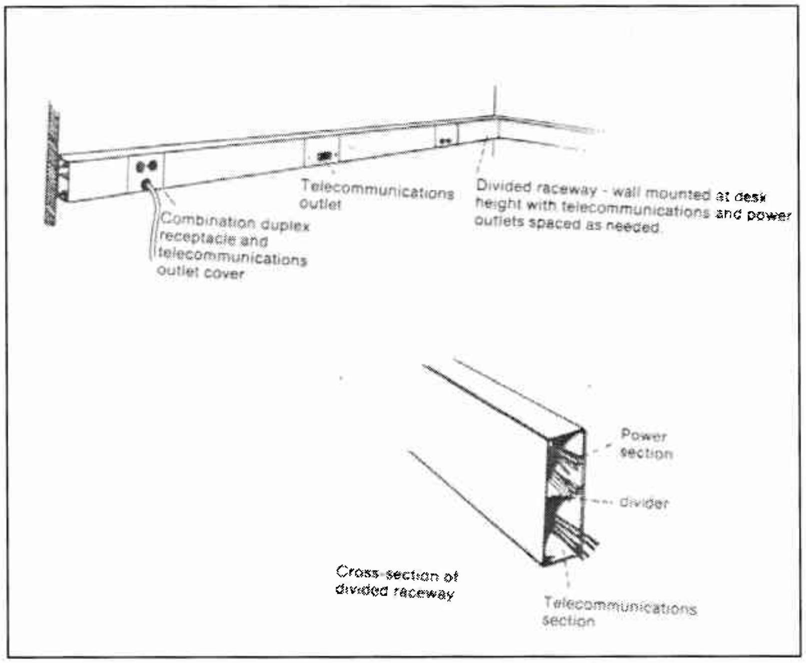


Figure 4-10 Perimeter Pathway with Interior Barrier

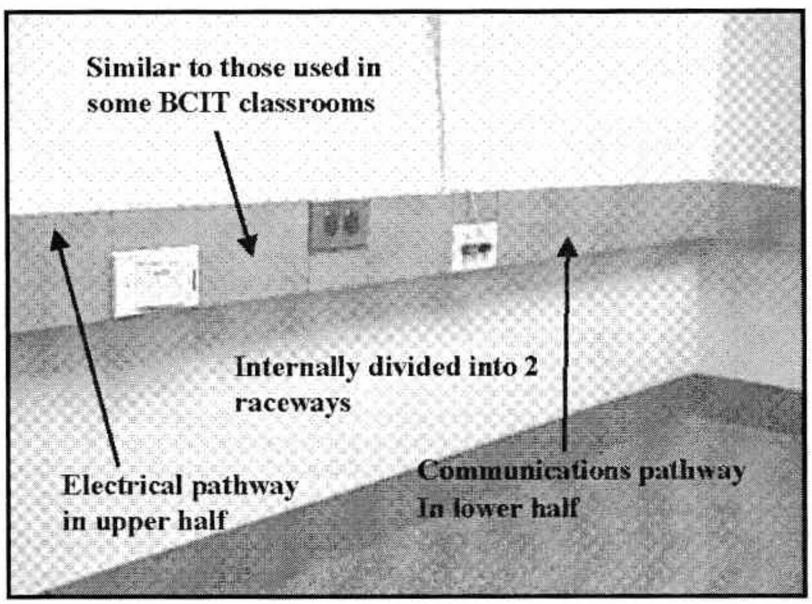


Figure 4-11 Perimeter Pathway

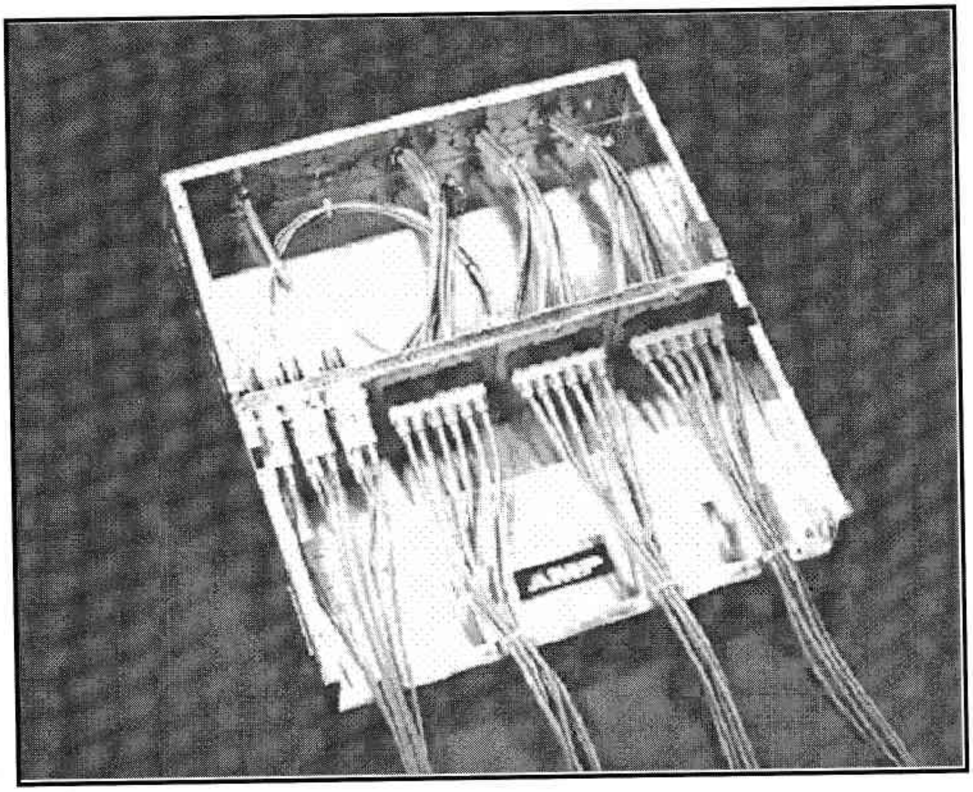


Figure 4-12 Fiber Optic Consolidation Point

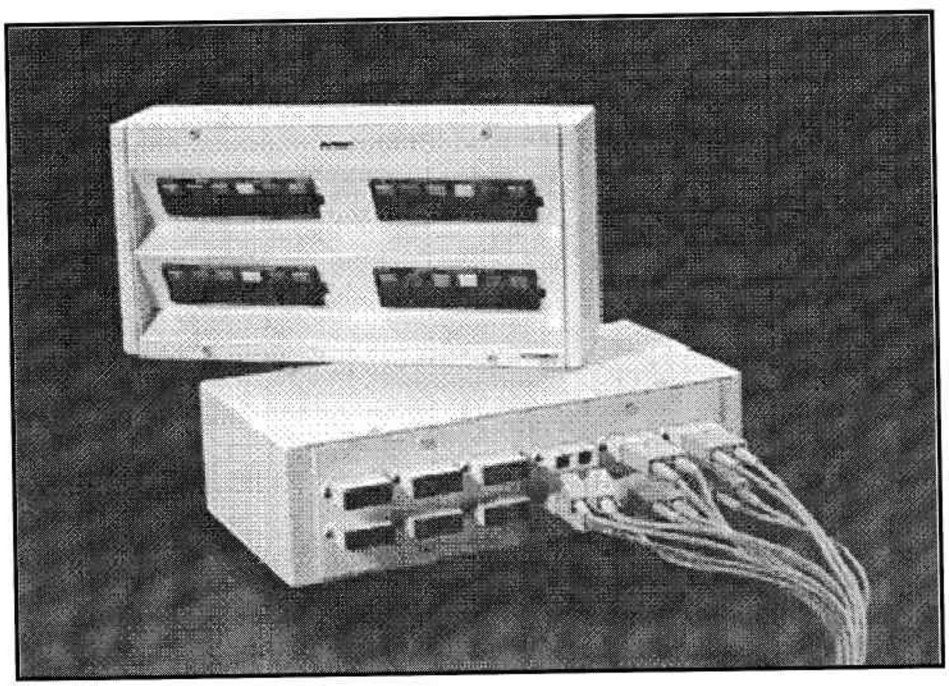


Figure 4-13 Fiber Optic MUTOA

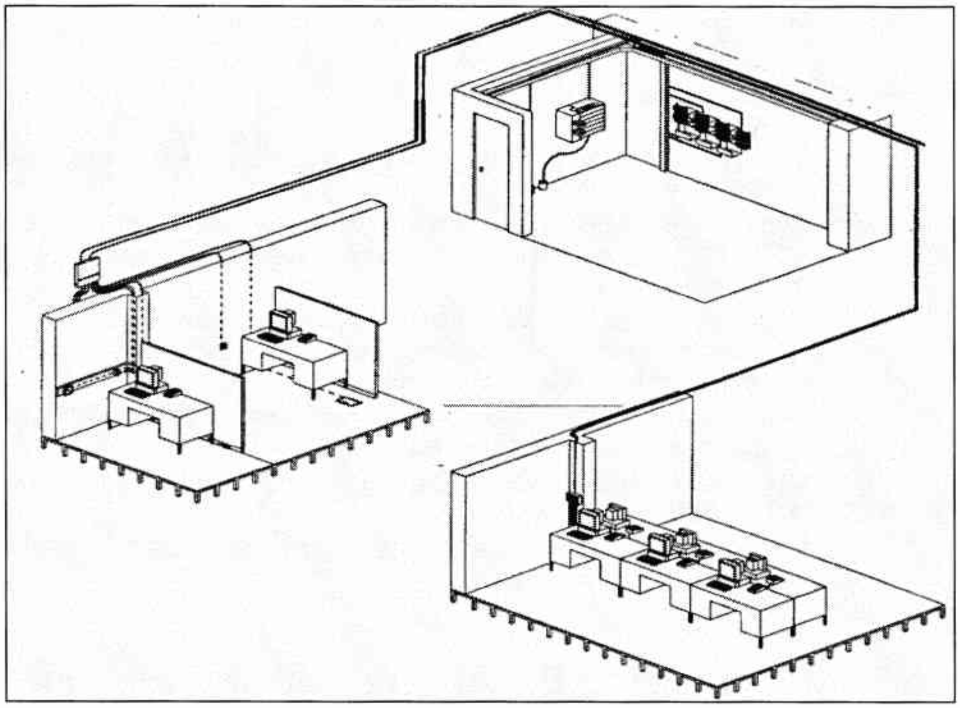


Figure 4-14 MUTOA and Consolidating Implementation

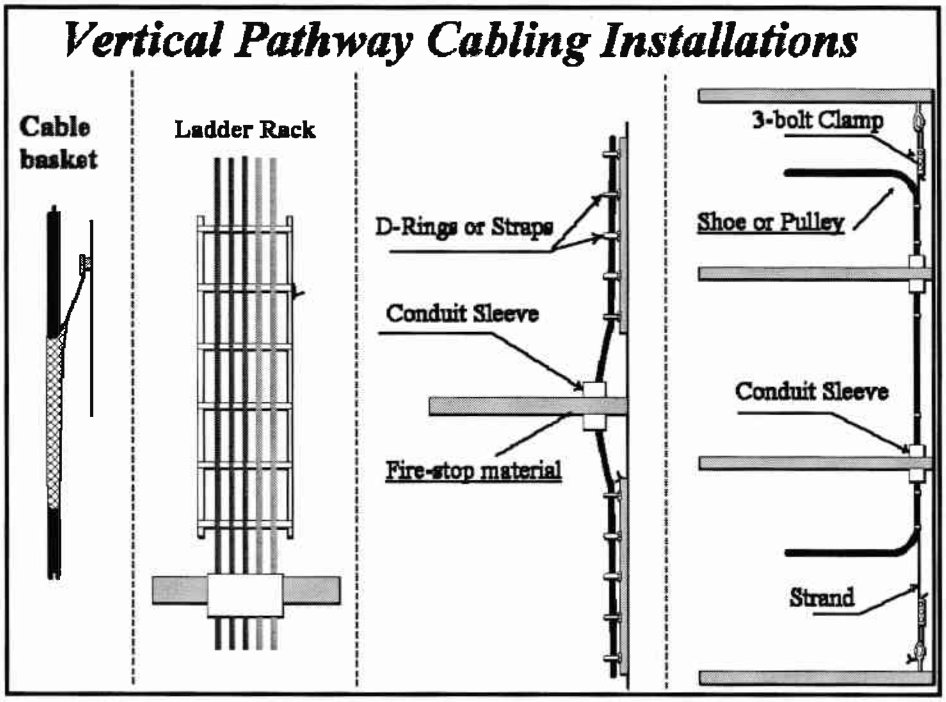


Figure 4-15 Vertical Backbone Pathways and Support Methods

Miscellaneous Pathways

Inter-stud Pathways

- Inter-stud pathways are the hollow spaces between studs, and the bore holds within the studs
- The pathway shall **not** have any sharp edges which could damage the cable jacket (e.g. metal stud holes should have grommets or bushings inserted in them)
- Under-carpet cables require a transition point between the telecommunications room and the work area outlet to accommodate the transition from round to flat cables
- Transition points are located in permanent areas such as building columns, permanent walls and flush floor boxes
- Over-floor pathways, exposed cabling, and poke-through systems are **not** covered by this standard
- Pathways shall **not** be routed through gaps between the floor and ceiling structure and curtain walls.

Clause 5 Inter-building Backbone Pathways and Related Spaces

General

- Backbone pathways support intra- and - backbone cables
- Backbones may be vertical (risers) or horizontal
- Intrabuilding pathways may be ceiling pathways, conduits, sleeves or slots, and trays, and provide pathways between Entrance Rooms, Telecommunications Rooms, Equipment Rooms or main terminal spaces
- Vertical pathways provide access to vertically stacked Telecommunication Rooms by means of sleeves or slots. If T/Rs are **not** vertically stacked, a Pathway shall be provided to link them
- Pull boxes and splice boxes are considered spaces

Design Guidelines

- The Equipment Room shall be connected to the backbone pathways to the main terminal space and the Telecommunications Rooms
- Ceiling areas of plenum or non-plenum spaces may be used as backbone pathways, if permitted by local codes
- Pull boxes shall be used for fishing the conduit, installing pull strings, or pulling cables to the box and then looping the cable onward
- Pull boxes shall **not** be used for splicing
- Splice boxes are to be used for splicing, in add to pulling cable
- Pull boxes and splice boxes shall be readily accessible
- Pull or splice boxes shall be placed in conduit where:
  The length is over 30 meters; there are more than two 90° bends
  Or there is a reverse (U-shaped) bend in the run

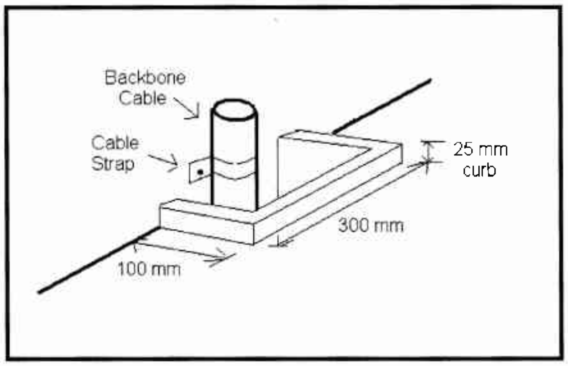


Figure 4-16 Floor Slot

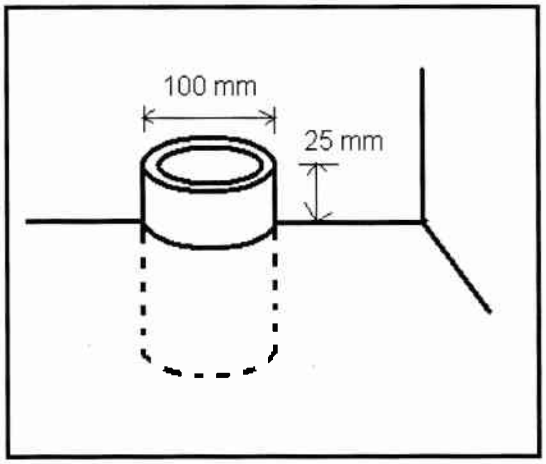


Figure 4-17 Floor Sleeve

Clause 6 <u>Work Area</u>

<u>Telecommunications Outlets</u> (Figure 4-18 & 4-19)

- Typical outlets are built into a 100mm by 100mm outlet box with horizontal cables terminated by connectors on a faceplate
- Outlets may also be built into furniture systems
- At least one location for the outlets shall be placed in every work area (10 m^2)

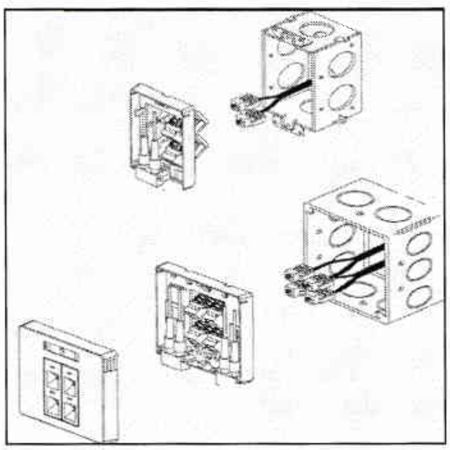


Figure 4-18 Telecom Outlets

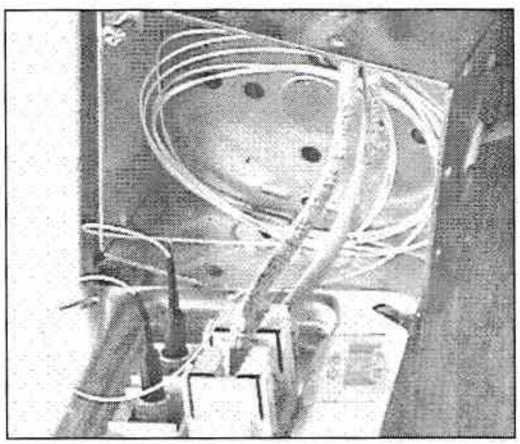


Figure 4-19 T/O with Slack

<u>Furniture Pathways</u> (Figure 4-20)

- Interior design, telecommunications and power distributions should be coordinated to avoid conflict
- Furniture pathways may be entered from walls, columns, ceilings or floors

- The interface between the building pathway and the furniture pathway should be safe, reliable, aesthetic and conceal the cable or cord
- A raceway should be provided between the building pathway and the furniture pathway
- Pathway interfaces shall **not** obstruct aisle spaces, where people walk or place their feet, or so as to create any other hazards
- Application planning requires the following information;
  Number, type and location of cable connections
  Diameter and minimum bend radius of each cable type
  A strategy for interfacing the building pathways
  Furniture pathway cross-sections and cable capacity
  The number of work areas in each furniture cluster

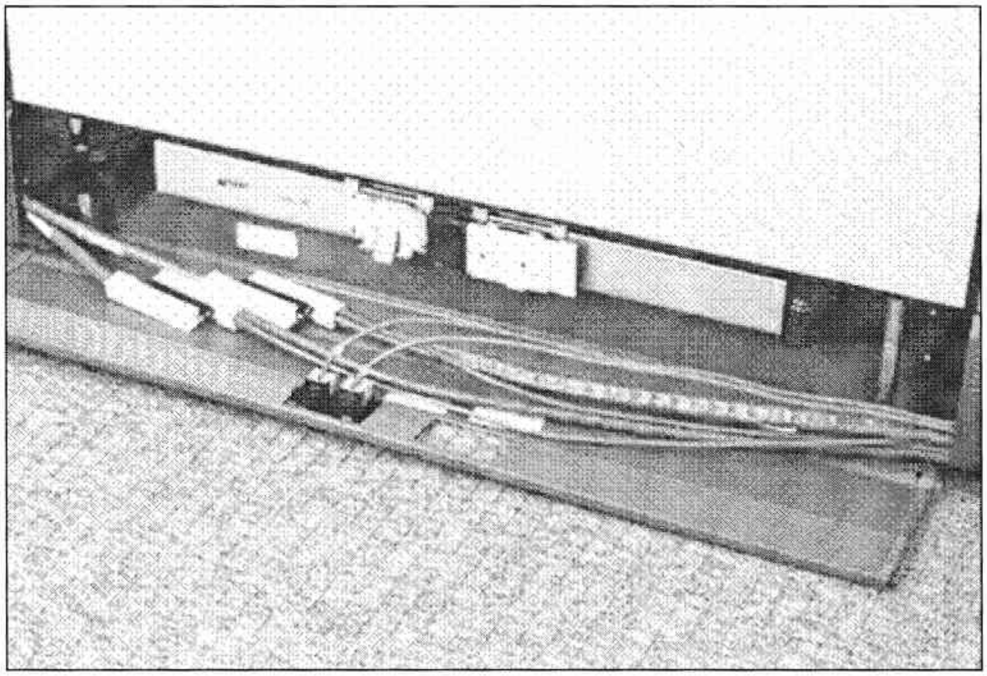


Figure 4-20 Furniture Raceway, Showing Telecom and Power Cables

- Fish and pull techniques should **not** be used. Cables should be laid in
- Access to the pathways should **not** be blocked
- Conduit bend radius shall be used in any pathway corner where a pull is required
- Separation between telecommunications cables and power cables shall meet the requirements of other sections in this document
- In multi-channel metallic pathways, the dividers between channels shall be bonded to ground

Furniture Spaces

- Furniture spaces can support slack cable, TUTOA and Consolidation Points
- Access to MUTOAs or Consolidation Points should provide security, service access, and at a convenient level for moves, adds and changes
- MUTOAs and Consolidation Points shall **not** be installed in furniture unless the furniture is permanently secured to the building structure

- Control centres, attendants and reception areas shall be provided with an independent and direct pathway to its serving Telecommunications Room or Equipment Room

Clause 7 Telecommunications Room

General

- The Telecommunications Room on each floor shall be able to contain the telecommunications equipment, cable terminations and associated cross-connect cabling
- It shall be located as close a practicable to the center of the area it serves
- All applicable codes shall be followed
- Horizontal pathways shall terminate in the Telecommunications Room located on the same floor as the area being served
- Seismic zone requirements shall be met
- The T/R shall be dedicated to telecommunications functions, and **not** shared with electrical installations, other than those for telecommunications
- The T/R may be shared by all the users of the area being served
- Equipment **not** related to or supporting telecommunications (e.g. piping, ductwork, etc.) shall **not** be installed in, pass through or enter the T/R
- There shall be a minimum of one T/R per floor, up to 1000 m^2 of floor space served
- Additional T/Rs shall be provided whenever the floor space exceeds 1000 m^2, or the horizontal distribution distance exceeds 90m
- T/Rs on the same floor shall be interconnected by a minimum of one trade size 3 conduit
- The T/R should be sized as per Table 4-1 below

Serving Area		Closet Size	
m^2	ft^2	mm	ft
1000	10,000	3000 x 3400	10 X 11
800	8,000	3000 x 2800	10 x 9
500	5,000	3000 x 2200	10 x 7

Table 4-1 Telecommunications Room Size

- minimum of two walls should be covered with 20mm (3/4 in) A-C fire-rated plywood, preferably void free, 2440 mm (8ft) high
- A minimum of two dedicated 120 V non-switched duplex outlets shall be provided, rated at 20 A. In addition, identified and marked convenience outlets shall be placed at 1.8 meter (6 ft) intervals around the perimeter walls
- If standby power is available, it should be provided as on automatic switchover basis
- Fire protection shall be provided as per code

- HVAC in the T/R shall be provided so as to maintain the same temperature as the adjacent office space 24 by 7
- Positive air pressure with a minimum of 1 air change per hour, or as required by code, shall be maintained
- Sufficient air changes shall be maintained to dissipate heat from all active devices
- HVAC serving the TR should be connected to standby power if it is available
- Figure 4-21 shows the concept of a Telecommunications Room

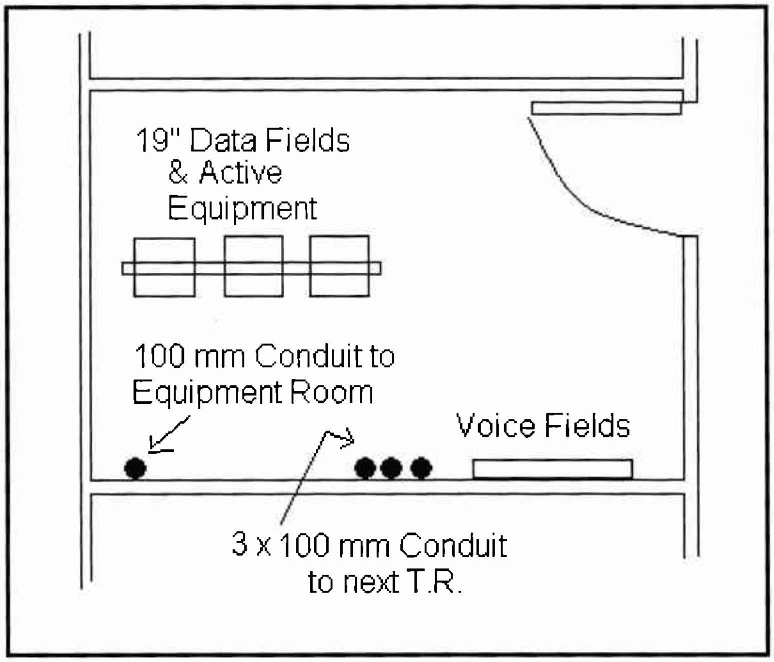


Figure 4-21 Conceptual Telecommunications Room

Clause 8 Equipment Room

General

- The E/R is a centralized space for telecommunications equipment (e.g. PBX, computing equipment etc.)
- Any or all of the functions of a T/R may be performed by the E/R
- The E/R shall be located away form EMI sources, especially power transformers, motors, generators, x-ray equipment, radio or radar transmitters
- The E/R shall be sized to meet known requirements of specific equipment
- A guideline for voice and data requirements in an E/R is 0.07 m^2 per $10m^2$ of work area space
- If multiple tenants are to share the E/R is shall be increased in size
- Special use buildings (e.g. hotel, hospital, laboratory), the E/R floor space shall be based on the known number of work areas (**not** on usable floor space) as per Table 4-2
- Environmental control equipment & UPS up to 100 kVA shall be permitted in the Equipment Room, UPS larger than 100 kVA should be located in a separate room
- Equipment **not** related to telecommunications shall **not** be installed in, pass through or enter the E/R
- Minimum clearance in the E/R shall be 2440 mm (8 ft)

- The E/R shall be protected from contaminants such as chlorine, dust, hydrocarbons, hydrogen sulphide, nitrogen oxides and sulphur dioxides
- Sprinklers or alternate fire-suppression systems shall be installed

Work Areas	Area m^2	Area ft^2
Up to 100	14	150
101 to 400	37	400
401 to 800	74	800
801 to 1200	111	1,200

Table 4-2 Equipment Room Floor Space

- Temperature and humidity shall be controlled to 18 °C to 24 °C, and 30% to 55% relative humidity
- A positive pressure differential with respect to the surrounding area should be maintained
- Portable fire extinguishers shall be provided in the E/R per local code
- Sizing of the E/R shall be determined by known requirements or the MDF or wall terminals, with room for future growth provided
- Buildings of up to 10,000 m2 of usable floor space may be equipped with wall mounted cross-connections, but buildings of over that size may require rack mounted cross-connections
-

Gross Floor Space Served m²	ft²	Wall Length mm	in
1,000	10,000	990	39
2,000	20,000	1060	42
4,000	40,000	1725	68
5,000	50,000	2295	90
6,000	60,000	2400	96
8,000	80,000	3015	120
10,000	100,000	3630	144

Table 4-3 Minimum Wall Termination Length

- Where a MDF is provided, minimum width of the E/R shall be 2.5 meters (8 ft)
- Table 4-3 specifies the minimum space on a 2.5 meter (8 ft) high wall
- The E/R should **not** have a suspended ceiling
- The main terminal space shall be connected to the backbone pathway

Gross Floor Space Served m²	ft²	Floor Space Dimensions mm	ft
10,000	100,000	3660 x 1930	12 x 6.5
20,000	200,000	3660 x 2750	12 x 9.0
40,000	400,000	3660 x 3970	12 x 13.0
50,000	500,000	3660 x 4775	12 x 15.5
60,000	600,000	3660 x 5600	12 x 18.5
80,000	800,000	3660 x 6810	12 x 22.5
100,000	1,000,000	3660 x 8440	12 x 27.5

Table 4-4 Sizing for Equipment Room

Clause 9 Entrance Facilities

General

- The Entrance Facility consists of the telecommunications service entrance to the building, consisting of the entrance through the building wall, to the entrance room or space
- The E/F may contain backbones to other buildings in a campus environment and antenna entrances
- Considerations for location include:
  - Contact carriers and providers to establish their requirements
  - Entrance of electrical, water gas and sewer shall be considered
  - Alternate entrance where security, continuity of service or other special needs apply
  - Line of sight and signal interference for antenna fields
- Equipment **__not__** related to support of telecommunications should **__not__** be installed in the E/F

Entrance Point

- The entrance point is the point where the entrance cable first enters the building through an exterior wall, concrete slab, etc.
- Entrance conduit should consist of a minimum of three trade size 4, with an additional three trade size 2 conduits recommended

Entrance Room or Space

- The entrance room or space provides a space for protectors, and may contain network interface devices
- Where the entrance room is required to support major equipment, it shall be sized accordingly
- Pathways between entrance point and entrance room shall be the same size as the entrance
- The entrance room shall be located in a dry area, as close as practicable to the entrance point, and next to the electrical service room to reduce the length of the bonding conductor
- For buildings exceeding 2000 m^2 of usable floor space, an enclosed room should be provided
- One wall should be covered with 20 mm A-C fire-rated plywood to 2440 mm high

Clause 10 Miscellaneous Items

General

- All telecommunications fire-stopping shall meet applicable codes
- Horizontal pathways for power and telecommunications shall be adequately separated as per Article 800-52 of ANSI/NFPA 70, and shall be applied to;

Separation from power conductors
Separation and barriers within raceways
Separation within outlet boxes or compartments

- The building shall be suitably protected from lightning
- Surge protection shall be applied at the electrical service entrance
- Requirements of the TIA/EIA-607 shall be followed
- Where further EMI and RFI reduction is required due to large motors etc. the following is suggested

Increased physical separation
Electrical branch circuit line, neutral and grounding conductors should be in close vicinity (e.g. twisted, sheathed, or taped together)
Provide surge protectors in the branch circuits
Use of a fully enclosed, grounded metallic raceway or grounded conduit
Install cables close to a grounded metallic surface

Annex A <u>Firestopping (normative)</u>

General

- Local Firestopping codes shall be met
- Fire-stops are used to prevent fire, smoke or water from passing through a barrier, as well as acting as environmental seals, or around parts that may move axially or laterally
- Fire-rated barriers are architectural structures or assemblies, established in accordance with building codes
- A disruption in the continuity or a fire stop nullifies the performance rating of the barrier

Categories of Firestop Systems

- Fire-stops are either mechanical or non-mechanical systems
- Mechanical systems use pre-manufactured flexible components shaped to wrap around cables, tubes and conduits
- Mechanical fire-stops provide

High durability
Reliable pressure and environmental seals
Re sistant to seismic vibrations
Suppo rt for the penetrating elements
EMI protection

- Non-mechanical fire-stops may be adapted for irregular openings and off-center elements
- Non-mechanical fire-stopping material includes

Putties, in the form of bars, sticks, pads or tubes
Caulk, in the form of tube delivery or pails
Cement-like materials, dry powders that are mixed with water to form a
paste that hardens
Intumescent wrap straps which are wrapped around pipes and cables
Silicone foams, normally two-part foams which expands to fill any voids
Pre-manufactured pillows, which contain a matrix of material that expands under high temperature

- See figures of fire-stops later in this section

See pages 95 – 98 for more detail on fire stops.

B: 606: TIA/EIA-606 & CAN/CSA T528-93

Design Guidelines for Administration of Telecommunications Infrastructure in Commercial Buildings

The following is a summary of the TIA/EIA-606 Design Guidelines for Administration of Telecommunications Infrastructure in Commercial Buildings document, and as such is subject to errors of omission and interpretation. Where accuracy and completeness is required, refer to the original document.

General

- Dated January 1993
- Developed in conjunction with EIA/TIA in U.S.

Clause 1 Introduction

General

- Administration of telecommunications includes the all the documentation and all telecommunication hardware, including;
  Labelling, records, drawings, reports and work orders for cables, hardware, patching cables, pathways, and spaces
- Administration should also include security, audio, alarms and energy management
- To provide uniform administration documentation independent of applications
- To be used by owners, users, manufacturers, consultants, designers, installers, and facilities mangers
- Documentation is expected to reflect changes as they happen.
- Migration of an existing legacy infrastructure may require facility analysis, and be difficult to fit into this standard
- This standard does not replace any codes, in part or in whole
- This Standard is a living document and is subject to revision and reviews

Clause 2 General

Scope

- Administration of new, existing or renovated commercial building or campus
- Areas to administer included are:
  Terminations in Work Areas, Telecommunications Rooms, Equipment

Room s and Entrance Facilities
Media (cabling) between terminations
Cabl e Pathways
Telecommu nication Spaces
Bonding and Grounding for telecommunications

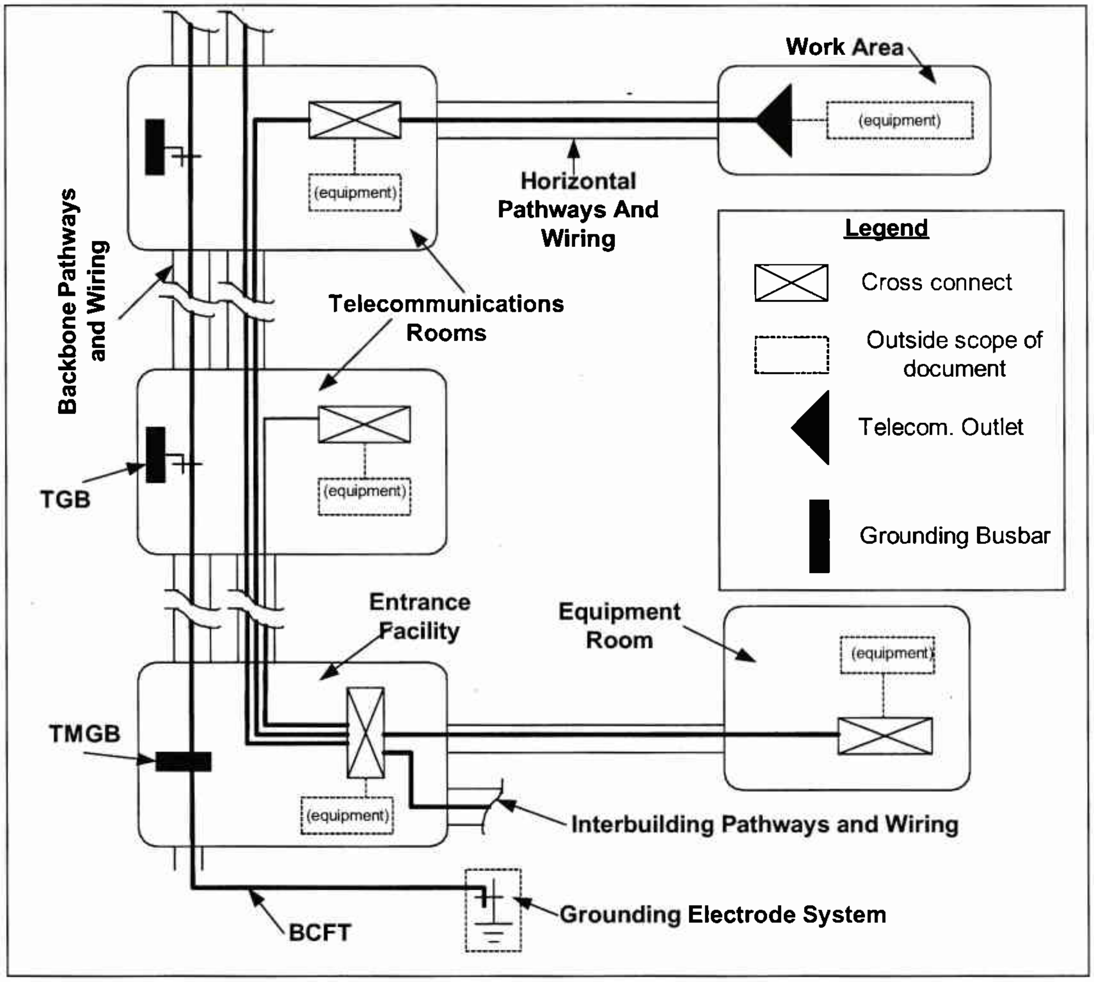


Figure 4-23 Scope of this Document

- Specifies the collection, organization and presentation of information
- As-built basis used
- Standard does not cover end-user equipment or application specific devices, although the administration documents may be used as a platform for such information
- Standard does not specify any safety requirements
- See Figure 4-23 for scope of administration

Clause 4 Administration Concepts

Identifiers

- Identifiers are given to elements of the infrastructure to be administered
- The element shall be physically labelled with its' identifier, and may include other desirable information
- Identifiers are used to link the element to its corresponding record
- See Figure 4-24 for relationship between Identifiers, Records and Linkages
- Each identifier shall be unique for that type of element:
  For example, no two cables shall bear the same identifier

- Unique identifiers across the system is recommended:
  For example, if HC01 is horizontal cable 01, do not label a horizontal cross connect as HC01
- Un-encoded identifiers only provide information on the hardware type, and sequential number:
- For example, horizontal cables identified as HC001, HC002 etc.
- Encoded identifiers provide additional information other than the basic hardware type:
- For example horizontal cable HC230-1A going to room 230, plate 1, outlet A on the plate
- See Figure 4-24 for conceptual view of identifying cabling elements

Records and Linkages

- Record defined as a collection of information related to a specific element of the structure
- Linkage are logical connections between Record and Identifier (e.g. Record information in one Record points to another Record)
- All Records shall include as a minimum Required Information and Required Linkages, the content of which is determined by the element being recorded
- Required Information may include:

Element Identifier (e.g. Cable number HC004)
Element Type (e.g. 4-pair Category 5e 100 ohm UTP)
Unused positions or pairs (e.g. Pairs 2, 3, and 4 unused)
Dama ged pairs (e.g. 1st conductor open on run)
Available pairs (e.g. 14 pairs in a 25-pair backbone cable)

- Required Linkages may include:

Terminations location and position on both ends of cables
Pathways used
Splice records
Grou nding record

- Optional Information and Optional Linkages may also be provided to increase the usefulness of the Administration Documents
- Optional Information may include:

Length of cables
Ownership of element (e.g. Telco demarcation, Tenant C owned
PBX Main cross connect, etc.)
Signal type carried (E.g. analogue voice, digital voice, etc.)
Conduit fill level, number of bends, associated pull boxes etc.
Space size (e.g. floor space in ER, TR etc.)
Door key number (for locked areas)
Area served (e.g. TR 304 serves 3rd floor, TR 404 serves 4th floor)
Drawings of specific circuitry, pathways, spaces etc.

- Optional Linkages may include:

Equipment records (e.g. Record of Model and serial numbers etc.)
User name and address (e.g. IP address, etc)
Source of power (e.g. Record of service panel and breakers)
HVAC Data (where a building HVAC Mechanical Record is kept)
Applicatio n Records

- See Figure 4-26 for conceptual record for a cable

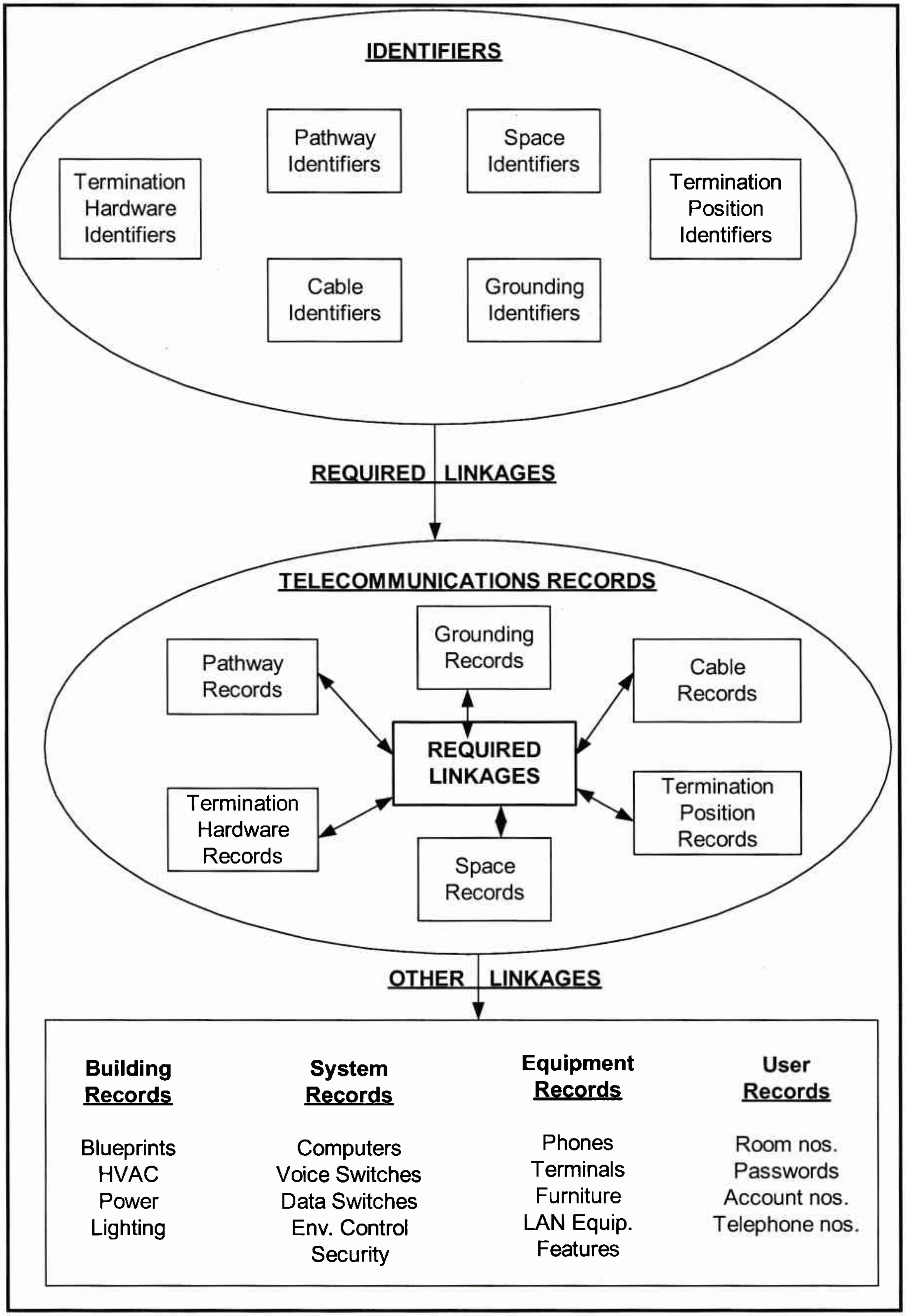


Figure 4-24 Identifier and Records Concepts

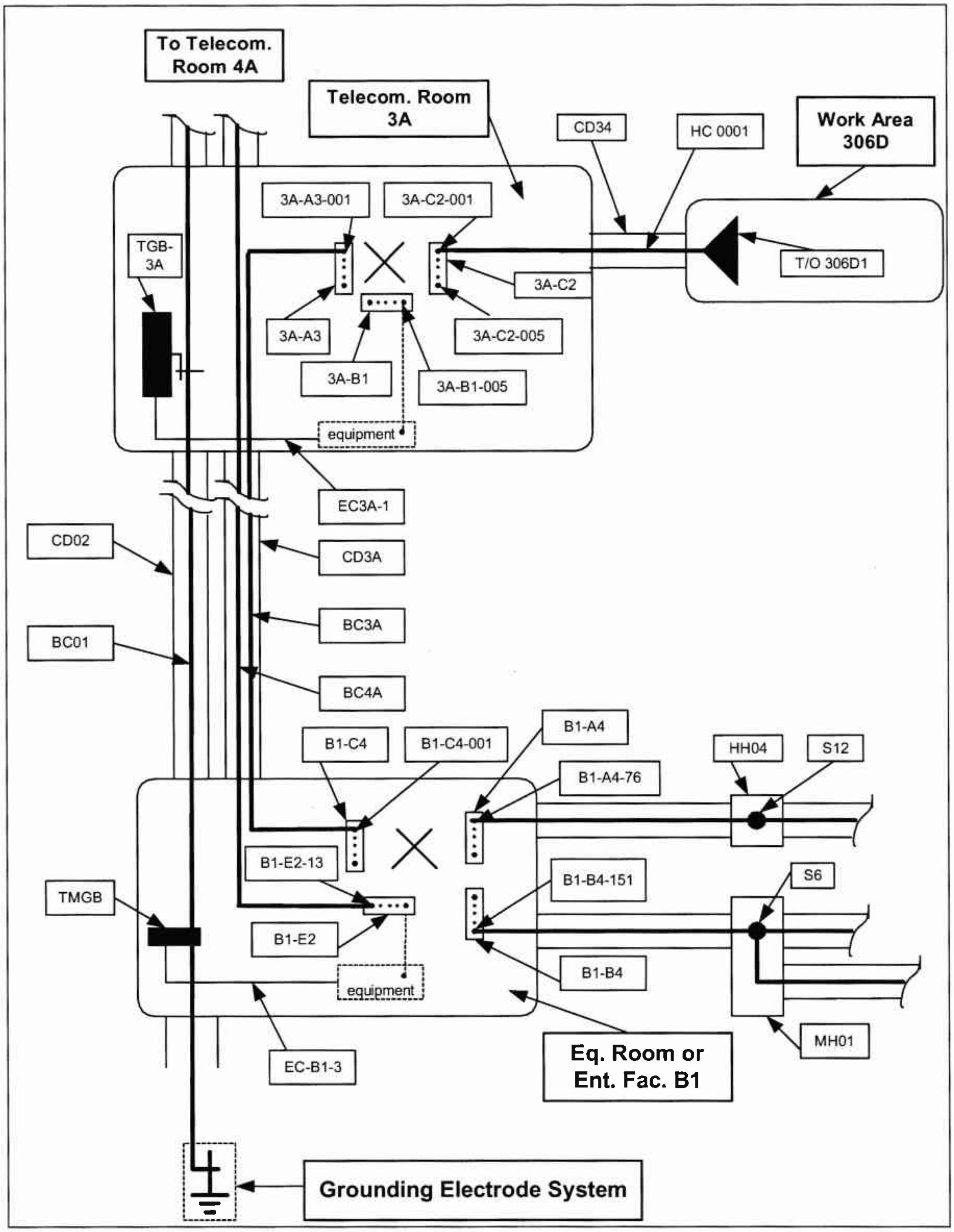


Figure 4-25 Example of Administration Point Labelling

User Code

- User codes are used as a terms of reference to provide a common access into the Records
- User codes may identify the physical and logical connectivity for aiding troubleshooting
- Examples of User Codes may include ;

A telephone number
A room number
A circuit number

Presentation of Information

- The Administration documentation include Labels, Records, Reports, Drawings, and Work Orders
- Reports present selected information from a single Record, to several linked Records. For example, a cable Report may include user name, terminal IP address, and Work Area See Figure 4-26
- Reports are a snapshot of use and condition of a particular type of element on a given day. A list of extension phone numbers and the users name & location can be considered a Report.
- Reports are usually produced to serve a particular function (e.g. available facilities, associate users and phone numbers, etc.)
- Reports do not necessarily be come part of the Administration Documentation
- Drawings present in graphic form the planning, installation and as-built structure. Annex C provides symbols which may be used in drawings
- Record drawings include floor plans, elevations and detail drawings of as-built elements in the structure
- Drawings should be come part of the Administration Documentation

For example, see Figure 4-28

Work Orders

- Work orders document requests for moves, adds and changes in the telecommunication structure
- Work orders should clearly state the work to be done, and the personnel involved in the physical work and the Record updates
- Work Orders should be kept on file, with completion or check-off processes

Required Information	Sample Data	
Cable Identifier	HC0001	
Cable Type	4-pair UTP, Cat. 5e	
Unterm. pr./cond. nos.	0	
Damaged pr./cond. nos.	0	
Available pr./cond. nos.	0	
Required Linkages		
Pr. 1-4 Term. Pos. records	**End 1**	**End 2**
	306D1	3A-C2-001
Splice records	n/a	
Pathway records	CD34	
Grounding records	n/a	
Optional Information		
Cable Length	45 m	
Univ. Prod. Code	n/a	
Ownership	Building owner	
Other Optional Information		
Other Linkages		
Equipment records	PC 1224	
Other Linked Records		

Figure 4-26 Conceptual Record for a Horizontal Cable

	Cable Reports		Date:		
Cable	**Pathway**	**Term Posn 1** **Term Posn 2**	**Space 1** **Space 2**	**Cable Type** **Cable Length**	**End Eqpt** **Application**
HC0001	CD34	3A-C2-001 306D-1	3A 306D	45 meters Cat 5e 4-pair	ENET 3 PC1212
HC0002	CD34	3A-C2-005 306D-2	3A 306D	43 meters Cat 5e 4-pair	ENET 3 PC 1257
BC-3A	CD3A	B1-C4-001 3A-A3-001	B1 3A	Cat 5e 25 pair 15 meters	ENET Backbone Layer 2 Switch

Figure 4-27 Conceptual Cable Report, in part

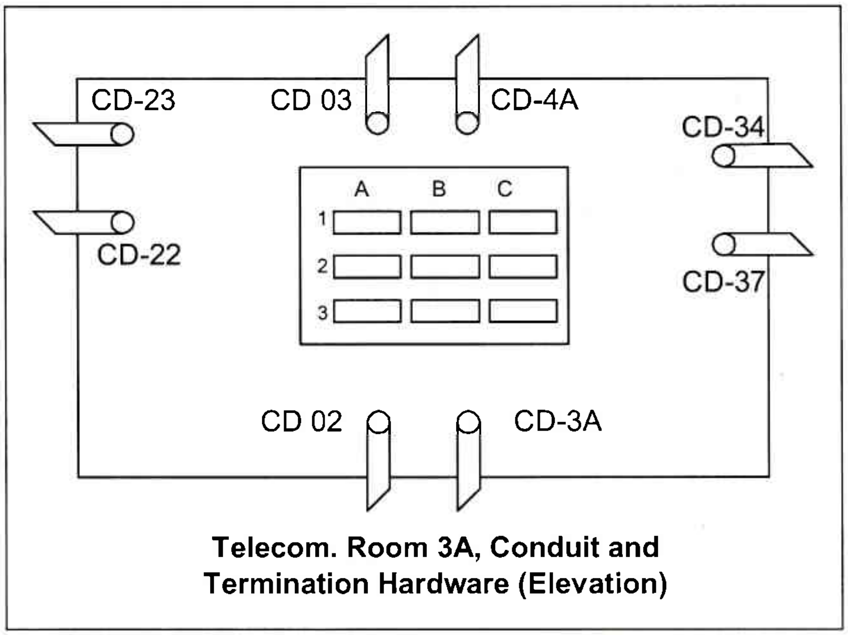


Figure 4-28 Conceptual Drawing of Conduits and Hardware in a Space

Clause 5 Pathway and Space Administration

General

- Pathways are defined as a conveyance for telecommunications media that join spaces together
- Pathways include: Conduit, ladder racks, raised floors, etc.
- Spaces include:
Equipment Rooms, Telecommunications Rooms, Work Areas, Entrance Facilities, Manholes, Hand-holes, Splice Boxes and Pull Boxes
- A pathway formed from two pathways of different types or sizes shall be administered as two separate pathways

Identifiers

- Pathway identifiers shall be unique, and shall be marked on each pathway or on its labels
- Partitioned pathways (duct banks or inter-ducts) shall be administered separately. Suggested identifiers may be suffixed (e.g. inter-duct pathway ID014 could have ducts ID014-a, ID014-B etc.)
- Identifiers on Pathways shall be present at all pathway endpoints located in TR
- Intermediate points on the pathway may be labelled
- Closed loop pathways (e.g. a cable tray following the parameter of a room) shall be labelled at regular intervals
- Intermediate points with 3 or more pathway endpoints shall have each pathway labelled
- Grid and multi-channel access distribution (e.g. cellular floors) shall be identified on record drawings
- Space identifiers shall be unique
- All spaces shall be labelled, preferable near their entrance

Record	Required Information	Required Linkages	Optional Information	Optional Linkage
Pathways	Pathway identifier Pathway type Pathway Fill Pathway loading	Cable records Space 1 & 2 records Pathway records Grounding records	Pathway length Pathway max. fill Pathway max. load Pathway condition Pathway usage Number of bends Drawing number Misc. Information	Other records
Spaces	Space Identifier Space type	Pathway records Cable records Grounding records	Space size Space location Area Served Door lock key number Misc. Information	Electrical records HVAC records Misc. Eqp't records

Table 4-5 Summary of Record Elements for Pathways and Spaces

Records

- Pathway and Space records contain specific information about the infrastructure
- Required Information and Linkages and Optional Information and Linkages are given in Table 4-5
- See Figure 4-29 for Sample Record of a Telecom. Room

Reports

- Reports and drawings summarize information from the records
- Work orders document changes to the infrastructure
- Pathway summary reports should list:

All pathways,
The pathway fill and
The pathway load
The content of the pathway (i.e. the cables therein)

- Space summary reports should list:

All Spaces
Space type
Space Location
Additional information may include interlinked records, Space sizes etc

Drawings and Work Orders

- Drawings for Pathways and Spaces shall be maintained, showing:

Size and location of pathways
Pathway routing, bend radii, pull boxes, wall penetrations, and fire stoppi ng details
Size and location of spaces
Plan and elevation views of all TR, ER, and EF spaces

- Work Orders shall be kept on file, and changes as a result of Work Orders shall be reflected in changes in associated records

Clause 6 Wiring System Administration

General

- Provides for administration of cables termination hardware, termination positions, and splices
- Changes to the infrastructure shall be reflected in the updating of the associated records
- Examples of labelling is provided in Figure 4-31
- Identical cables spliced together shall be administered as one cable
- Termination hardware may contain more than one termination position
- Administration is based on the wiring hierarchy TIA/EIA 568

Required Information	Sample Data
Space Identifier	3A
Space Type	Telecom. Room
Required Linkages	
Pathway records	CD02, 3A, 4A, 03, 22, 23, 34, 37
Cable records	EC-31-1/25, BC-01, HC0001,0002,0004, 0023 to 0048
Grounding record	TGB-3A
Optional Information	
Space Size	3 m * 3.3 m
Space Location	3rd floor, Grid A4
Area Served	3rd Floor, North side
Door Lock Key Number	A27
Misc. Information	
Other Linkages	
Electrical Records	Panel Board 3C
HVAC Identifier	
Equipment Record	Switch 3A

Figure 4-29 Sample Records for Pathways and Spaces

Identifiers

- Each cable shall be given a unique cable identifier
- Each cable shall be marked with its cable identifier
- Horizontal and Backbone cables shall be labelled at both ends; Additional labels may be required at mid points (e.g. in a pull box)
- Cables of differing conductor counts spliced together may be administered as separate cables; use of identifier suffixes, based on the cable with the largest cable count is suggested
- When a cable routes through multiple pathways, the pathway record shall refer to all pathways used
- Each termination hardware shall have a unique identifier: use of grid identification is suggested (e.g. BIX Blocks labelled alphabetically horizontally and numerically vertically C2 is over three, down 2)
- Each termination hardware shall be labelled with its identifier
- A unique identifier shall be assigned to each termination position
- An identifier shall be marked on each termination position label where possible
- Labelling at the Work Area may include the termination position identifier
- Splice enclosures shall be given a unique identifier, and it shall be labelled

Records

- Records are typically used in conjunction with other records
- Cable records shall document every pair or conductor in the cable
- Cable records shall include all required information and linkages as shown in Table 4-6
- Every cable record has a linkage to two termination positions
- Every termination position shall be recorded
- Termination hardware records shall include all required information and linkages as shown in Table 4-6
- Termination position linkage fields may be used individually or in groups (e.g. 4 pairs in a cable). See Figure 4-30.
- Termination position records shall include all required information and linkages as shown in Table 4-6
- User code identifiers may be used as termination position identifiers (e.g. termination position H4A-09 to outlet J4A-09)
- Splices shall have a unique identifier, and the splice record shall include all required information and linkages as shown in Table 4-6

Reports

- Cable summary reports should be available listing:
- All cables, the type and termination positions
- Additional information may be desirable in the summary report
- End to end circuit report that traces connectivity may be desirable reporting:
- User code, termination positions, cables, and other information as desired
- Cross-connect reports should be created listing all cross-connections within a space

Record	Required Information	Required Linkages	Optional Information	Optional Linkage
	Cable identifier Cable type Unterm. pair/cond. nos. Damaged pair/cond. nos. Available pair/cond. nos	Term. position records Splice records Pathway records Grounding records	Cable length Univ. product code Ownership Cable manufacturer Date of installation	Other records
Termination Hardware	Term. H/W identifier Term. H/W type Damaged position no.	Term. position records Space records Grounding records	Protection type Current rating Voltage rating Misc. information	Other records
Termination Position	Term. position identifier Term. position type User code Cable pair/cond. nos.	Cable records Other term. position records Term. H/W records Space records	Signal carried Cross-conn. type Cross-conn. pos'n End-end losses Misc. information	Other records
Splice	Splice identifier Splice type	Cable records Space records	Splice eq. used Misc. information Owner	Other records

Table 4-6 Summary of Record Elements for Cable Types

Record Drawings and Work Orders

- Record drawings for the wiring sub-system shall be maintained
- Drawings shall show:
  - Location of all cable terminations
  - Location of all backbone cables
  - Routing of all cables maybe desirable
  - Applicable identifiers shall be shown on the drawings
- Backbone drawings should show plan and elevation views of all backbones, as installed and routed through TR, ER, EF, and Pathways
- Floor plans shall show the locations of all TR
- Work Orders shall be kept on file for all cable or splice changes
- Records effected by changes shall be updated
- Work Orders may included additional information as required

Required Information	Sample Data	
Cable Identifier	BC-3A	
Cable Type	25 pair Cat 5e	
Unterm. pr./cond. nos.	0	
Damaged pr./cond. nos	0	
Available pr./cond. nos	Pair 25	
Required Linkages	**1st End**	**2nd End**
Pair 1 Term. Posn. Record	B1-C4-1	3A-A3-1
Pair 5 Term. Posn. Record	B1-C4-2	3A-A3-2
Pair 9 Term. Posn. Record	B1-C4-3	3A-A3-3
Pair 21 Term. Posn. Record	B1-C4-6	3A-A3-6
Pair 25 Term. Posn Record		
Splice Record	n/a	
Pathway Record	BC-3A	
Grounding record	n/a	
Optional Information		
Cable Length	15 m	
Univ. Prod. Code	n/a	
Ownership	Building owner	
Misc. Information		
Other Linkages		
Other Records		

Figure 4-30 Example of a 25-Pair Cable on Patch Panels

Clause 7 Grounding and Bonding Administration

General

- Changes to the Grounding and Bonding elements, labels, records, reports and drawings shall be covered by this document

Identifiers

- The Telecommunication Main Grounding Busbar (TGMB) shall be uniquely labelled as such
- A unique identifier shall be assigned to each Telecommunication Bonding Backbone (TBB) attached to the TMGB
- A unique identifier shall be assigned to each Telecommunication Grounding Busbar (TGB), and these identifiers shall use the prefix TGB
- Bonding conductors extending from the TGB to equipment should have unique identifiers

Labels

- The Bonding Conductor for Telecommunications (BCFT) connecting the TMGB to the building ground shall be labelled at each end
- The BCFT labels shall be as close as possible to the connection points, while staying visible, with a label similar to Figure 4-31
- The TMGB shall be labelled "TMGB".
- Each TBB attached to the TMGB shall be labelled at both ends of the conductor
- Each TGB shall be labelled
- It is suggested that all conductors bonding equipment to a TGB be labelled

WARNING

IF THIS CONNECTOR OR CABLE IS LOOSE OR MUST BE REMOVED PLEASE CALL THE BUILDING TELECOMMUNICATIONS MANAGER

Figure 4-31 TMGB to Building Ground Label

Records

- G & B records include the TMGB record, the Backbone Bonding Conductor records and the TGB records
- Table 4-7 shows the required and optional information and linkages required
- Where the grounding and bonding conductors use pathways, the Pathway record provides the administration

	Required Information	Required Linkages	Optional Information	Other Linkages
TMGB	TMGB Identifier Busbar Type Grounding Cond. Identifier Resistance to Earth Date of Measurement	Bonding Cond. Reports Space Records	Service Panel Records	Other Records
Bonding Conductors	Bond. Cond. Identifier Bond. Cond. Type Busbar Identifier	Grounding Busbar Record Pathway Record	Service Panel Records	Other Records
TGB	Busbar Identifier Busbar Type	Bonding Cond. Records Space Records	Service Panel Records	Other Records

Table 4-7 Summary of Record Elements for Grounding & Bonding

Reports

- Summary G & B reports should list the TMGB, TGB, and all attached backbone bonding conductors
- Additional information in the summary report may be desirable

Drawings and Work Orders

- Record drawings for the G & B sub-system shall be maintained.
- Drawings shall show:
  Location of grounding electrode
  Routing of the BCFT conductor from grounding electrode to the TMGB
  All TGB attached to backbone bonding conductors
  Routing of all bonding conductors may be desirable
- Drawings should show plan and elevation views of all bonding conductors as routed through pathways, TR, ER or EF
- Work orders shall be maintained on file for all G & B repairs or changes, and records updated accordingly
- The work order shall include bonding conductor and busbar identifiers, and types
- Additional information on the work order may be desirable

Clause 8 Labelling and Colour Coding

Labels

- Rules for labelling are based on requirements of companion ANSI/EIA/TIA standards
- Physical and colour coding of labels and general practices are covered
- Labels may be adhesive, insert or other types

Adhesive labels

- Adhesive labels shall meet legibility, defacement, adhesion required by UL 969 (EIA EP-7)
- Labels shall meet exposure requirements required by UL 969 for indoor use
- In harsh environments, sleeving or tags may be more suitable
- Adhesive cable labels should have a durable substrate, a white writing surface, and a clear "tail" which would wrap around the cable at least 1.5 times around the cable
- Insert labels shall also meet requirements of UL 969
- Outside labels shall meet outside requirements of UL 969
- Tie-on labels shall be treated as insert labels for the purpose of this document
- Labelling practices should be consistent across the installation
- Labels should be easily seen
- Precautions should be taken where labels on covers (e.g. pull boxes) are used, where covers may be inadvertently exchanged
- Other attributes such as non-conductivity maybe required
- All bar codes shall be either Code 39 or Code 128 (EIA/TIA-359A)

Colour Coding of Termination Fields

- Colour coding in this standard is based on EIA/TIA 568 hierarchical star backbone
- Termination labels identifying both ends of the same cable shall be the same colour
- Cross-connects are usually performed between two different colour fields
- See Table 4-8 for colour code assignments

Termination Type	Colour	Pantone	Comments
Demarcation point	Orange	150C	Central office terminations, carrier side
Network connections	Green	353C	Network connections or auxiliary circuit terminations, customer side
Common equipment	Purple	264C	Major switching and data equipment terminations MDF
First Level backbone	White		MC-IC cable terminations
Second Level backbones	Gray	422C	IC-TC cable terminations
Station terminations	Blue	291C	Horizontal cable terminations
Interbuilding backbone	Brown	465C	Campus cable terminations
Key telephone systems	Red	184C	Key telephone MDF
Miscellaneous	Yellow	101C	Auxiliary, maintenance alarms, security

Table 4-8 Field Colour Codes Specified in EIA/TIA 606

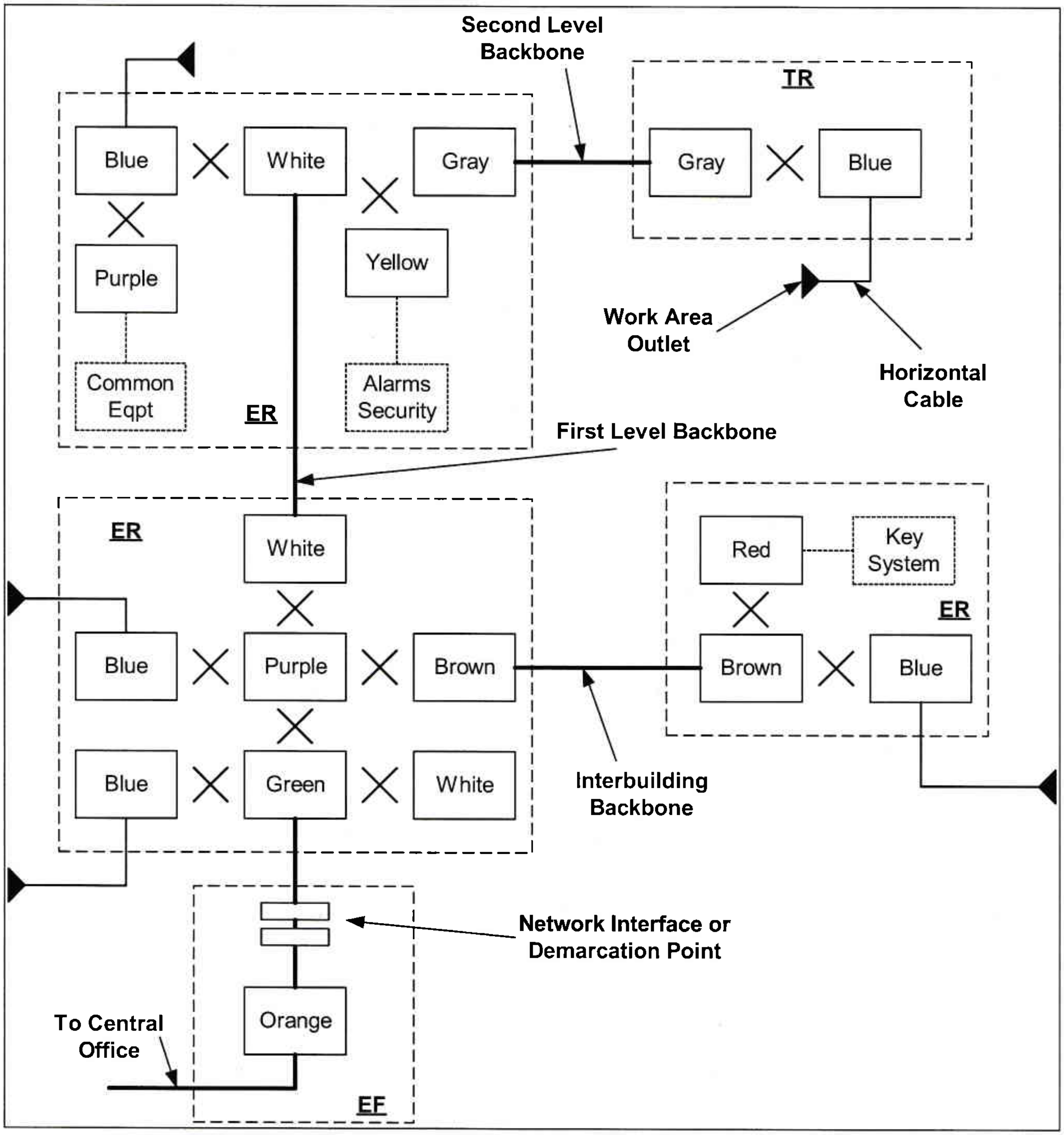


Figure 4-32 Conceptual Drawing of the Administration Colour Fields

C: TIA/EIA-607 & CAN/CSA T-527-94

Commercial Building Grounding and Bonding Requirements for Telecommunications

The following is a summary of the CAN/CSA-T530-M90 Building Facilities, Design Guidelines for Telecommunications document, and as such is subject to errors of omission and interpretation. Where accuracy and completeness is required, refer to the original document.

General

- Telecommunications refers to all forms of information that are conveyed with the building
- Grounding and bonding to support the star topology
- Seeks to ensure a reliable grounding system for telecommunications
- To be used with TIA/EIA-569, TIA/EIA-568B, TIA/EIA-607 and other documents

Clause 1 Introduction

Purpose

- To design and install a grounding system without needing prior knowledge of the networks to be installed
- To support a multi-vendor, multi-product environment
- To support the design, renovation and maintenance of new or existing buildings
- To support advanced technology network structures and telecommunications equipment
- The Standard **does not** replace any related federal, provincial or municipal codes

Clause 2 Scope

General (Figure 4-33)

- Requirements for a uniform building grounding and bonding systems
- Works in conjunction with other grounding systems in the building
- This Standard may be used for new or renovated structures and specifies the requirements for;
  A ground reference for the networks, within the EF the ER and the TR
  Connecting pathways, cable shields, conductors & hardware
- This Standard **does not** provide requirements for;
  Grounding and bonding equipment
  Surge current or breakdown voltages
  Verification tests for grounds or bonds
  RFI/EMI mitigation methods
  Protection or Arresters
  User safety
  Practices of local carrier companies
  Electrical service entrance

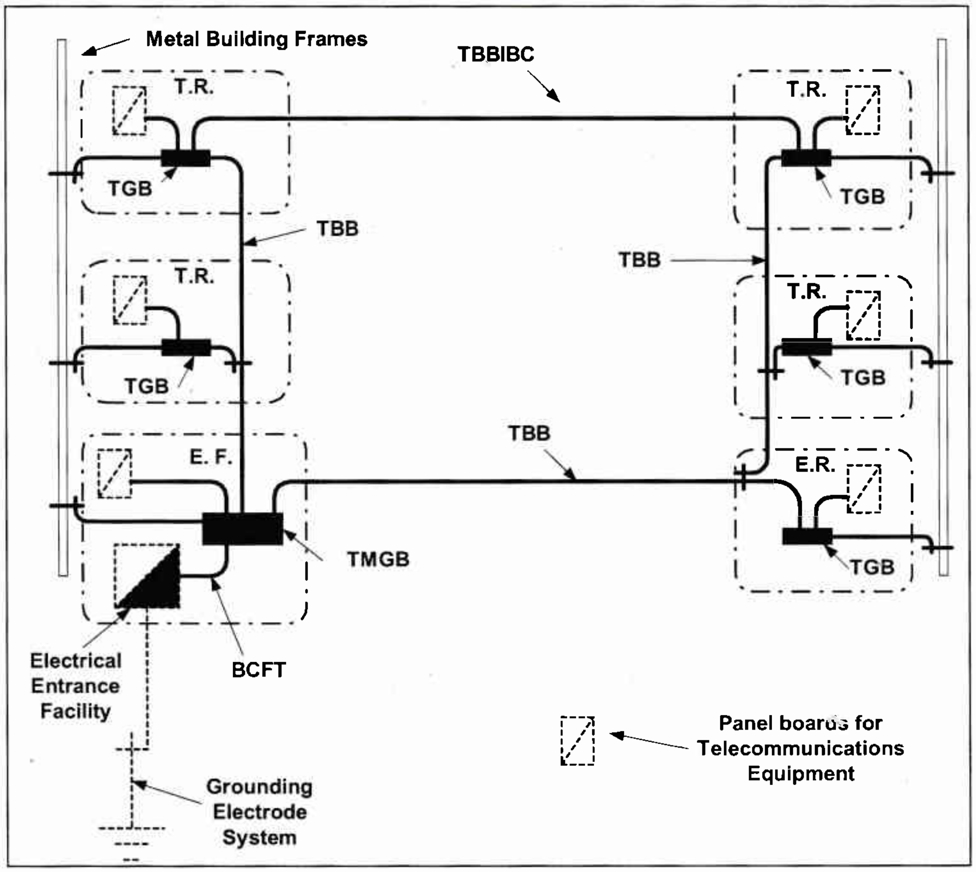


Figure 4-33 Scope of this standard for Commercial Buildings

Clause 4 <u>Overview</u>

- The electrical service entrance is covered by other codes
- Applicable G & B codes shall be met

<u>Overview of G & B Structure</u>

- Five major components of G & B systems are;
  Bonding Conductor for Telecommunications (BCFT)
  Telecommunications Main Grounding Busbar (TMGB)
  Telecommunications Bonding Backbone (TBB)
  Telecommunications Grounding Busbar (TGB)
  Telecommunications Bonding Backbone Interconnecting Bonding Conductor (TBBIBC)
- Other components are;
  Pathways and spaces (TIA/EIA 569)
  Building cables and terminations (TIA/EIA 568-B)
  Equipment Rooms, Entrance Facilities and Telecommunications Rooms
- Electrical service panels, are **<u>not</u>** part of this standard, but are depicted because they are integral to the G & B system

Clause 5 Components of the Grounding and Bonding Infrastructure

General:

- All bonding conductors shall be;
  Listed by a recognized testing laboratory (e.g. C.S.A. or U.L)
  Insulated copper conductors AWG 6 or larger
  Insulation colour shall be green
- Bonding conductors should **not** be placed in ferrous metallic conduit. If necessary to place in a conduit over 1 meter in length, the bonding conductors themselves shall be bonded to each end of the conduit
- Each telecommunications bonding conductor shall be labelled as close as practical, while remaining visible, to the termination points at each end of the conductor (Figure 4-34)

WARNING

IF THIS CONNECTOR OR CABLE IS LOOSE OR MUST BE REMOVED PLEASE CALL THE BUILDING TELECOMMUNICATIONS MANAGER

Figure 4-34 Bonding Conductor Label

Bonding Conductor for Telecommunications

- The BCFT shall bond the Main Telecommunications Busbar to the service equipment (power) ground, Figure 4-35
- The BCFT shall be at minimum the same size (6 AWG) as the Telecommunications Bonding Backbone

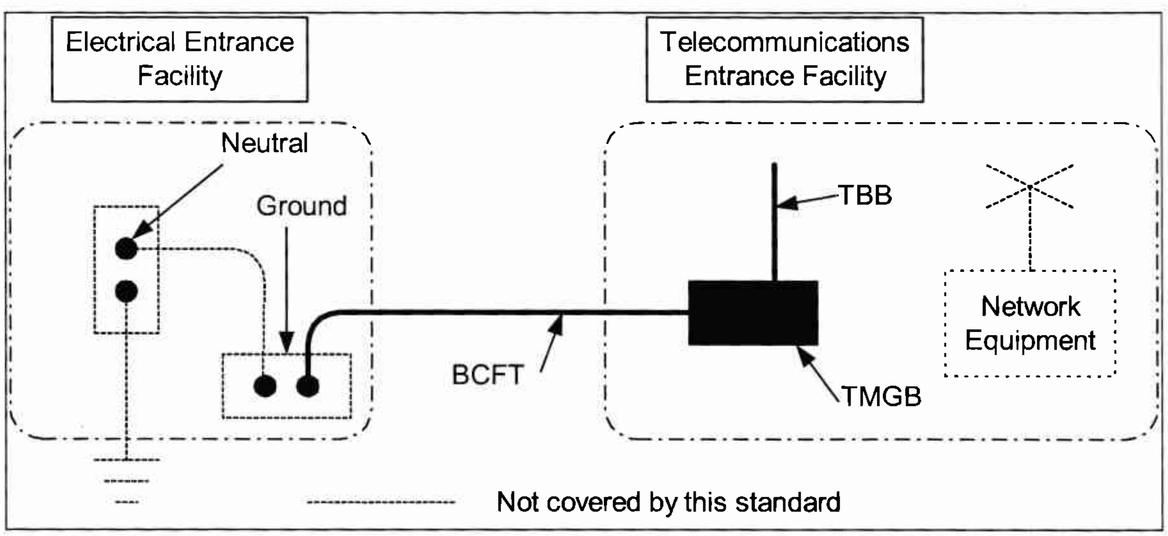


Figure 4-35 Connection from TMGB to Service Equipment Ground

Telecommunications Bonding Backbone

- The TBB connects all Telecommunications Bonding Busbars in the building to the Telecommunications Main Grounding Busbar
- The TBB's main function is to reduce or equalize voltage differentials between Network systems connected to the TBB
- The TBB is **not** to be used as the only ground fault return path in the building
- The TBB originates at the TMGB and follows the cable backbone pathways to connect to all Telecommunication Grounding Busbars throughout the building
- The building water pipes shall **not** be used as a TBB
- Metallic cable shielding shall **not** be used as a TBB in new construction
- The TBB shall be at least AWG 6, copper conductor with green insulation
- Where two vertical TBBs are used in building, they must be bonded together at the top floor, and at a minimum every 3 floors between, using a TBBIBC
- Protect TBB conductor from physical or mechanical damage

Telecommunications Main Grounding Busbar

- The TMGB serves as;
  A dedicated extension of building grounding electrode system
  The central attachment point for all TBBs
  The grounding busbar for equipment located in the same space
- The TGMB shall be accessible to telecommunications personnel
- The TGMB should be located in the E.R., but should be located to minimize the length of the Bonding Conductor for Telecommunications
- The TMGB shall be;
  A predrilled copper busbar, with the holes sized and spaced for the type of connectors to be used
  A minimum of 6 mm thick, by 100 mm wide and
  Long enough for immediate an future needs
  It is desirable to have the busbar electrotin plated
  Cleaned prior to connecting conductors (Figure 4-36)

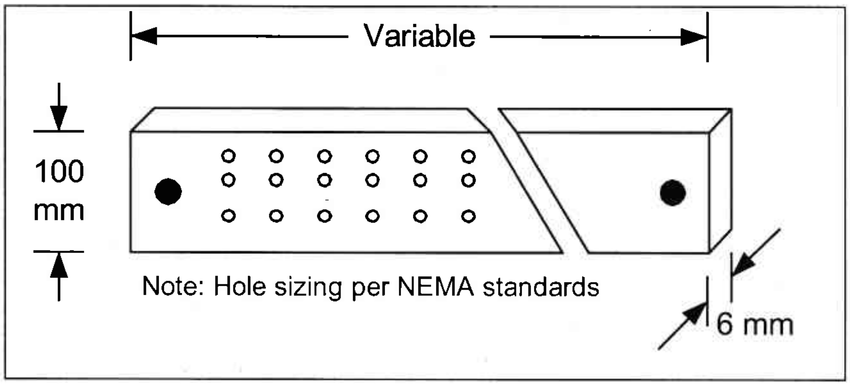


Figure 4-36 Typical TMGB Busbar

- Where a panel board (service panel) for telecommunications is co-located with the TMBB, that panel board's Alternating Current Equipment Ground (ACEG), or if an ACEG is **not** present, bonded to the panel boards case
- The TMGB shall be as close as possible to the panel board, and installed in accordance with electrical codes

- Bonding conductors for network equipment may utilize 1-hole lugs or equivalent, but 2-hole compression connectors are preferable
- The TMGB shall be insulated from it's support with a 2 inch separation
- All metallic raceways for the network located in the same room as the TMGB shall be bonded to the TMGB

Telecommunications Grounding Busbar

- The TGB shall be;
  A pre-drilled copper busbar with hole sizing and spacing for the type of
  c onnectors used
  A minimum of 6 mm thick, by 50 mm wide
  Long enough to meet current and future requirements
  Preferably electrotin plated, or cleaned prior to installing a connector
- TBBs and other TGBs in the same space shall be bonded together
- Bonding conductors shall be continuous and routed by the shortest path in a straight line
- Where a panel board for telecommunications is co-located with the TGB, the ACEG or panel board enclosure shall be bonded to the TGB
- The TGB shall be located as close to the panel board as the electrical code permits
- When the panel board for telecommunications is **not** co-located with the TGB, consideration should be given to bonding its ACEG or enclosure, to the TGB
- The TGB shall be bonded to the TBBIBC where required
- All metallic raceways for the network co-located with the TGB shall be bonded to it.
- TBBs shall be connected to the TGB by 2-hole compression connectors
- The TGB shall be insulated by a minimum of 2 inches, from its support

Metal Building Framing

- All bonding conductors and connectors for bonding the metal frame of a building shall be listed for that purpose
- Where the building metal frames are effectively grounded, each TGB shall be bonded to the framework by an AWG 6 conductors
- Where the metal framing is external to the TGB space, and readily accessible, it should be bonded to the TGB
- Where horizontal frame members are permanently electrically bonded to the vertical frame members, the TGB may be bonded to the horizontal member, if the distance is shorter
- There is no requirement to bond steel rebar in concrete

Clause 6 Telecommunications Entrance Facility

- The EF. is where the outside cable plant (common carrier cables) joins the inside cable plant
- The EF. may contain antenna entrances, and telecommunication equipment
- It is desirable that all utilities enter the building in close proximity to one another
- The EF is the desired location of the TMGB
- The TMGB so located may serve as a TGB for co-located equipment as appropriate
- The TMGB should be located so the BCFT has the straightest and shortest distance to the telecommunications primary protectors

- The TGMB is the common point for all grounding conductors in that location
- The TGMB shall be located as close as code permits to a panel board serving telecommunication equipment
- When a panel board is **not** co-located with the TGMB, the TGMB shall be located close to the backbone pathways, always using the shortest and straightest route to the panel board
- The TGMB shall also terminate
  Bonding conductors to the building side of an isolation gap in a pathway
  Metallic shields for backbone cables
  Telecommu nications primary protectors
  Multiplexing or Fiber Optic equipment with built in grounding busbars

Clause 7 Telecommunications Room and Equipment Room

- Each Telecommunications room and Equipment Room shall contain a TGB
- Size is covered in Clause 6
- The TGB shall be insulated from its support by 2 inches
- Multiple TGBs may be installed in the same space to reduce bonding conductor lengths
- All TGBs in the same space shall be bonded together
- If no panel board for telecommunications is present, the TGB should be located near the Backbone pathway

D: Building codes:

The construction of a new building is subject to many restrictions and regulations at the federal, provincial and local levels. When working on the construction site, you are subject to a number of different sets of rules. Agencies such as Worker's Compensation Board, the Electrical Safety Board, and the Municipal Building Inspectors all have a say in how and what the trades-people can do. It is not the purpose here to go deeply into this multi-faceted and often confusing state of affairs, but only to touch the surface of this issue to arise awareness of these issues.

The General Contractor on the building site is responsible for the actions and practices of the various sub-trades, and is the best person to discuss any issues you may have. Some of the regulations you are working under will vary from area to area, where others will remain constant. Safety issues like safety-toe shoes, hard hats and ear plugs are usually constant, while others may differ from jurisdiction to jurisdiction.

The Federal Government of Canada sets the minimum standard for building construction and electrical safety standards, but the Provincial and Municipal Governments may pass rules, regulations or by-laws which require tighter restrictions than the federal standards.

1) Fire walls

The purpose of a fire wall is to provide a barrier to a fire, and they are rated in minutes or hours of fire suppression time. Largely, the function of the room determines if a fire wall is required or not, and how long the fire "separation" has to last.

Possible sources of fire, for example areas with volatile vapours or electrical/mechanical equipment, would normally have fire separation. Rooms in an apartment building or a hotel may also have fire walls if the structure built to the current code standard. Cement floors in a commercial structure may also be used as a fire wall. If so, the floor will be equipment with conduit to provide access from floor to floor. Special fire-stopping drywall supports a 45 minute fire wall, while 6 inches of concrete provides could provide up to 4 hours of protection.

It is not always easy to determine if a wall is in fact a fire wall. Rooms with fire walls will normally have a solid wood or metal door, and be enclosed on all 6 sides (top and bottom as well as the sides). The fire separation must run from one floor to the next floor above, with no break. If the fire wall is made from fire-proof drywall the drywall sheets will be fully taped, even above the dropped ceiling, as the object is to make the wall smoke tight as well as fire proof. Where glass is used, as in a door or a sidelight for a door, it must have wired glass fitted. Where openings are required, the opening must be fitted with a "closure" device such as a self-closing door. When in doubt, check with the general contractor or check the floor plan. It is generally the job of the drywall contractor to provide fire-stopping material for all holes in the firewall, and so they are also a good source of information. And you will have to advise the drywall crew of any fire walls you ran cable through.

The best way to treat a fire wall is to route your cables around the walls. Unless there is a need to pierce a fully enclosed room, do not. If a telecommunications outlet is needed, keep the hole as small as possible. In some cases, a metal conduit will have to be provided, which is then fire-stopped with special materials once the cables are installed. See the figures below for recommended methods of fire stopping.

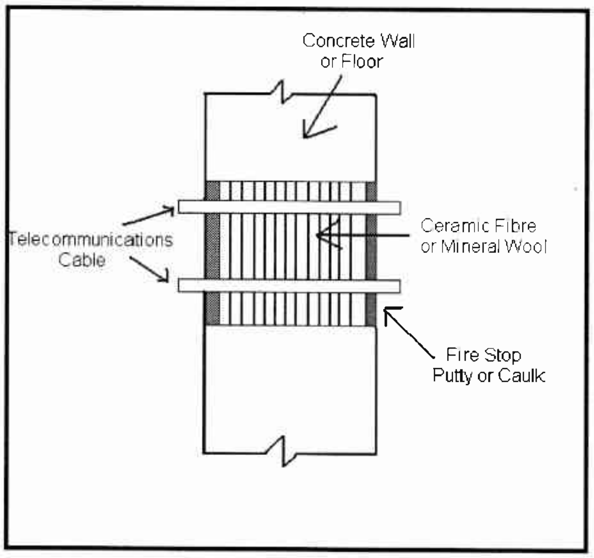


Figure 4-37 Cables and Putty

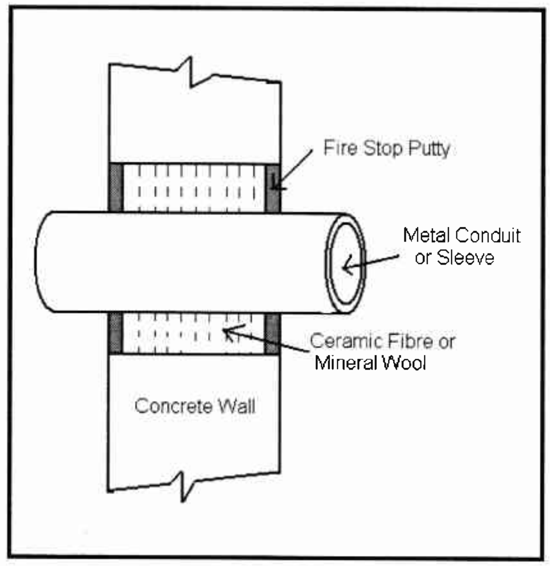


Figure 4-38 Cables with Putty & Fibre

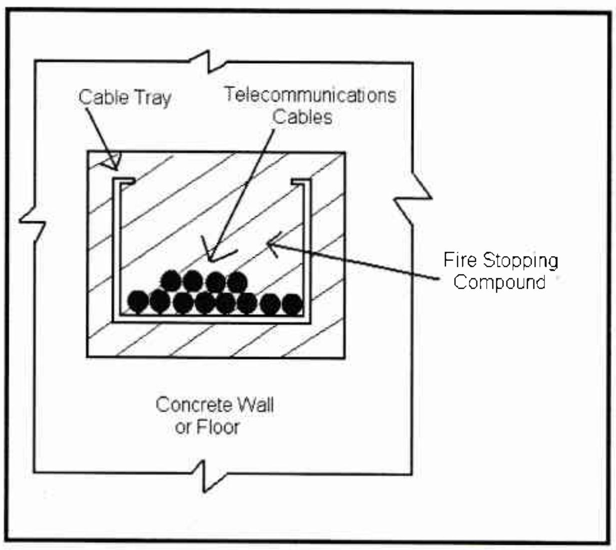


Figure 4-39 Cable Tray and Firestop

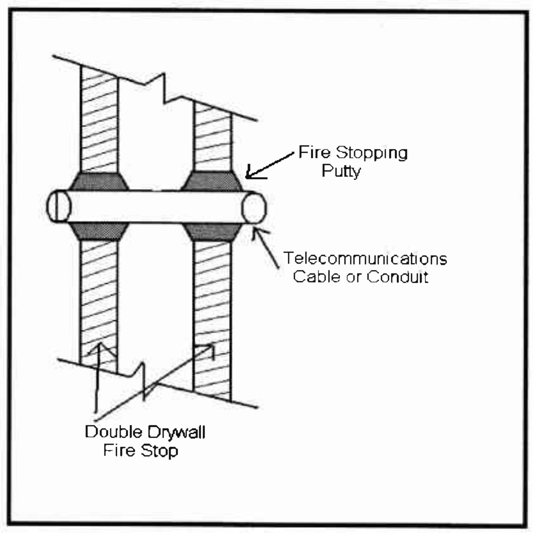


Figure 4-40 Conduit through Gypsum Board

2) FT ratings

Telecommunications cables for interior use have to have specific jacket markings, one of which is the Flame Test or FT rating, of the cable. For commercial use, telecommunications cables have to be either FT-4 or FT-6 rated.

FT-4 cables have the characteristic that although the cable will burn, it does not burn at a high enough temperature to sustain burning. Once the cable is far enough away from the source of flames, the cable stops burning. These cables were designed to be run in a vertical configuration, say from the basement up to the 10th floor of a building. The issue here is that we do not want a fire in the basement, or any other floor, to migrate "up-hill" on the cables.

Cables with an FT-4 are often referred to as "riser" cables, as the rise from one floor to the next. Most often is structured cable systems, these are backbone cables. An alternate form of jacket marking is the use of an "R" in the functional abbreviation. CMR cable, for example, means Communications Riser-rated. Likewise OFNR means Optical Fiber, Non-conductive, Riser-rated.

FT-6 cables also meet the FT-4 standard, but have the additional characteristic that the smoke from a burning FT-6 cable is non-toxic. Many FT-4 cables use PVC jackets, which produce hydrochloric acid (in gaseous form) when burning. The issue here is that a small fire in a breathable air space (such as the plenum space above most dropped ceilings) could produce toxic fumes, which could injure, or even kill a person on a different floor from where the fire is. The central air-conditioning and heating would cause the smoke fumes to spread throughout the building, possibly even before any fire alarms or smoke detectors went off.

Although the building code of Canada does permit short runs of FT-4 (or non-plenum) cable in a plenum air space, many contractors are now using FT-6 cables exclusively. The cost of the cable is a little bit more, but the contractor knows the FT-6 cable can be placed anywhere.

Occasionally you may come across FT-1 cable, which is only suitable for "combustible" buildings that is, buildings with wood frame construction, and no fire walls. Single family dwellings are often considered combustible, but again this can vary from one city to another, so when in doubt check with the contractor or the local building or electrical inspectors.

3) Vapour barriers

Most modern structures have a vapour barrier on the interior side of all outside walls. This plastic, air-proof barrier stops outside air from migrating through the walls of the building, and into the interior. The outside air often has a different humidity than the inside air, and is rarely at the same temperature as the inside air. This results in moisture collecting in the stud space of outside walls, if no vapour barrier is present. This moisture can lead to wood rot, reduces the efficiency of the insulation, and will be an open invitation for insects to move in.

Many municipal codes require that all punctures of the vapour barrier must be sealed. This would include a telecommunications box placed in an outside wall. When installing boxes in external walls, always use a plastic vapour barrier box around the electrical box, and reseal the hole in the vapour barrier with builders tape.

4) Electrical Safety codes: Low Energy ticket

In British Columbia, a technician can write a special Low Energy test, which gives the licensee the right to request building permits for electrical wiring, as well as provides evidence of the technical ability of the holder. The process may have changed, but in the late 90s required 1600 hours of low energy (i.e. less than 100 watts) experience, which can be documented by a letter from your employer, and successfully passing a written test on the Canadian Electrical Code.

This ticket will not let you work on 110VAC circuits, except in limited cases, but, should you become a contractor, will allow you to pull permits on electrical work, provided you have a licensed electrician with a suitable ticket.

Section 4 Summary

TIA/EIA569A: Building Facilities, Design Guidelines ...

- Horizontal Pathways
  - Stud Space, Cable Tray, Plenum Spaces
  - Utility Column and Surface Raceways
  - Conduit, Pull Boxes, 90 degree Elbows
  - Furniture Pathways
- Backbones, Riser Supports
- Telecommunications Outlets
- Multiple User Telecommunications Outlets and Consolidation Points
- Sizing for Telecommunications Rooms, Equipment Rooms and Work Areas
- Entrance Facility
- Fire Stopping

TIA/EIA-606: Design Guidelines for Administration ...

- Requirement for Documentation
- Identifiers:
  - Cables, Grounding, Terminators, Outlets, Pathways
- Records and Linkages
- Pathway and Space Administration
- Wiring Systems Administration
- Grounding and Bonding Administration
- Labelling and Colour Coding Termination Fields

TIA/EIA-607: Commercial Building Grounding and Bonding Requirements...

- Components of Grounding and Bonding Infrastructure
- Bus-bars and Conductors
- Entrance Facility
- Equipment and Telecommunications Rooms
- Building Codes
  - Municipal ahead of Provincial or Federal Codes
  - Fire walls and Fire Stopping
  - FT Ratings on Cables (CSA/UL)
- Vapou r Barriers
- Electrical Safety Codes

Section 5 Designing and Planning a S.C.S. Infrastructure

A) Design Process

Ideally, a proposed building would come with a full set of drawings identifying all telecommunications spaces and outlets, with the pathways located, and cables and hardware to be used; the reality is usually quite different. Often the only information the cable installer is provided with is the location of the outlets, telecommunications rooms and the equipment rooms where the cables are to be run to. After that, it is up to the installer to select the best routes, to select the location for the terminating hardware, and to provide adequate grounding and bonding, and (sometimes) to provide a record of the infrastructure.

- Standards and Specifications
- Raceway capacity, placement and mounting
- Horizontal routing and placement
- Backbone routing and placement
- Cross-connects and terminations
- Cable Management
- Labeling
- Testing
- Documentation

Figure 5-1 S.C.S. Design and Installation Steps

On occasion, the building architect will call in a SCS designer when the initial building drawings are being done. This to ensure the structure is designed to meet the various cabling standards. Doing the design at this stage will increase the chances that the building will be able to support current and future telecommunication needs. Even when this is done, however, the actual routing, outlet placement and hardware to be used maybe left up to the company providing the cable installation.

The TIA/EIA 569 document is of particular importance to a building architect as it provides a standard set of telecommunications spaces required for SCS. Following this document ensures that the finished building has sufficient space in the form of Telecommunication Rooms, Equipment Rooms, Entrance Facilities and pathways to support the current, and near future generations of network infrastructures. Wall space, floor space, and pathway spaces are based upon usable floor size and work area allotments. Many of the items covered in TIA/EIA 569 have to be built into the architectural drawings, because they can not be “retro-fitted” once the building is complete. Conduit placement in concrete and selection of raised or cellular floors being are two prominent cases where a little foresight can save a bundle of money.

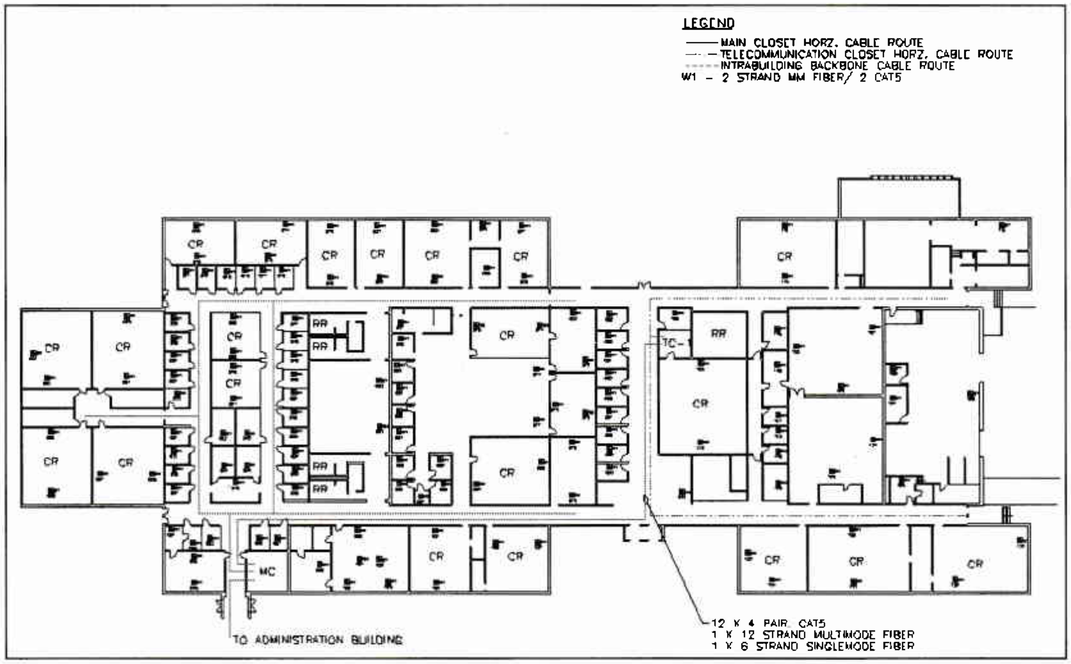


Figure 5-2 Conceptual Floor Plan

In the case of a renovated building, or a network up-grade, the client and general contractor do not have a lot of choices, as the most desirable location for specific equipment may not be available. When this happens, a good cable design can still be provided to the client as long as a thorough site inspection is undertaken by a knowledgeable cable designer or estimator. It rarely pays to re-use any hardware or cables from an old structure, as the category of performance can not be guaranteed, but pathways and spaces may be reconfigured to suit the new infrastructure.

Generally the process of bidding on a cable job consists of a number of very distinct steps, each of which requires a collection of related information and analysis before the next step can be taken. In the following discussion, we will look at the process as it may be performed by an independent cabling contractor, working in a newly constructed building.

B) The Request for Quote

A request for quotes on the cabling for a new building may be called at any time up to the time the stud walls are up. The job of the estimator is to analyze the floor plans in order to determine the material and labour requirements to complete the job. Once the costs are determined, the companies' profit margin is added and the estimate is complete.

The Request for Quote documentation from the prospective client should contain:

- A floor plan, possibly showing outlet locations and telecommunication spaces
- Any Standards and Specifications the client wants complied with (e.g. TIA/EIA 568)
- A section stating that all national, provincial and municipal building, electrical and safety codes will be complied to.
- Any special requirements the client requires
- A phone contact for questions or clarification
- A construction schedule

C) The Bid Checklist

The estimator has to analyze the plans and determine if any information is missing or requires clarification. A Bid Checklist is drawn up, containing basic information about the job quote. This would include the categories of outlets required, type of distribution (ceiling space, conduits etc.), level of performance certification required, and any special requires particular to this job. Responsibility for the conduit placement and firestopping is also determined. Normally, each cabling company will have their own process in place to guarantee that all the items to be provided to the client are accounted for, and will be included in the bid.

It is to everyone's benefit to have all the details laid out. The client wants all the bids to meet a certain specification, so he does not have to compare "apples to oranges," and the bidders want to ensure that their bid is not undercut by someone offering a substandard product, or a cheap version which may lead to cost over-runs (above the artificially low price) in order to make the network work correctly.

If the estimator requires further information not contained in the RFQ, he will request clarification from the client. The client should advise all interested parties of the clarification or changes, once again ensuring all the bidding parties are bidding on the same job.

D) Sizing the Structure for the Future

Once the total scope of the job is determined the next step is to look for possible options or upgrades to the client's request. This may include recommendations for future sizing, suggestions for improved services, or other "value-added" features which may make the client's network function better.

Sizing is always an issue, as a network that barely meets current requirements may require expensive up-grades in the near future, but most clients prefer to keep the cost to a minimum. If conduit in concrete is the standard pathway, all pathways should be oversized allowing future Horizontal or Backbone Cables to be pulled in at a later date. Backbone Cables are often installed in "phases" as the company grows. These cables typically are run as vertical risers and are easily added at a later date, provided the backbone pathways are oversized.

Horizontal Cables are another matter. These cables typically terminate in different areas and therefore require separate pathways, and adding these cables at some later date can be expensive and require surface mounted raceways. Open office areas can be easily treated by providing consolidation points with surplus conduit fill available, but fixed work area outlets can present a large problem, specially where plenum or sub-floor space is not available.

Suggestion for improved services will often come from the cable companies past experiences, and may require the bidder to explain the issues surrounding the client's RFQ. An example could be an RFQ requesting two applications (e.g. voice and 10-Base-T) on a single cable. This can be done by providing the 4, 5 pair as a voice service, while 1, 2, 3, 6 is used for the 10-Base-T. This is certainly a "cheap" way to get voice and data services, but fails to provide an up-gradable infrastructure. Should the client decide at a later date to go to a 100 megabit network, the split-application cables would not support the faster service, even if only the 1, 2, 3, 6 conductors were used, and protocols using all 4 pairs for data transfer would, of course, be prohibited. The cost of rewiring all the outlets, and running in new cables, would be greater than the original cost.

A second scenario is the client who wants to cut corners by not installing patch panels in a data network. "It's cheaper to place module ends on the Horizontal Cables," he will say, "than it is to buy patch panels and cords." From an initial cost point of view, he is likely correct, but field installed modular ends can not be guaranteed to meet category requirements, and tend to be mechanically unsound. The extra cost of patch panels for horizontal and main terminations (a few hundred dollars) would soon be overcome by the cost of repairing the connectors, degraded service due to impedance mismatches and reflection, and a lowered performance of the data and voice networks.

E) The Estimate Process

The estimator than calculates the length and types of cabling required, the number of outlets, cross-connect hardware, and rack spaces required. Sizing of the cables and terminations would meet current and expected future needs. The grounding and bonding system is also specified, and a meeting with the electrical contractor may be required to resolve building ground issues. A meeting with the communications carriers, the telephone companies, and cable providers may also be required to determine their needs as far as demarcations, sizing, and entrance access to the building.

Once the proposed structure is conceptualized, a cost estimate has to be prepared. A list of all the required hardware, pathway, cabling and labour is written up. The cable company's mark-up is then added, and the first draft of a quote is prepared. At this point the cable installation company will likely have a meeting of the manager, the account salesman, and the design person to ensure that all the requirements of the client are being met in their quote, and that the quote is competitive while still making money for the installers.

Possible upgrades, modifications, and recommendations will also be described, and these may be added to the quote documentation as an Appendix. The cable company has to have strong arguments to convince the client to agree to these added costs, and the best way is to display the long term benefits to the client. Increased productivity, reduced downtimes, and a lower cost of future growth are the main reasons why a client could be persuaded that the RFQ should be extended. Needless to say, the conscientious cable installation company will not use this route to "sell the customer up" to something they do not need.

Finally, the estimator places a cost on the work to be done. Outlets and hardware are counted, cable lengths are calculated, and labour times estimated. Added costs in the RFQ such as conduit placement and firestopping are factored in. The estimator then "marks-up" the estimate to provide the cable company with a profit, and to provide some leeway in case of unforeseen costs or events.

Any options or recommendations are priced out separately, so that the client can compare the basic RFQ with the other bids on a one-to-one basis.

The finished quote is then sent to the client before the deadline for their perusal. The client may select any bid (which is not always the lowest bid), or request supplemental information on the bids. Often the contact includes a pay-out schedule, which may see the client making three or more payments during the course of the installation. This ensures that the job will get done to the client's satisfaction. In most cases, the contract will be let at this time, and the cable installers scheduled for the work.

F) The Rough In

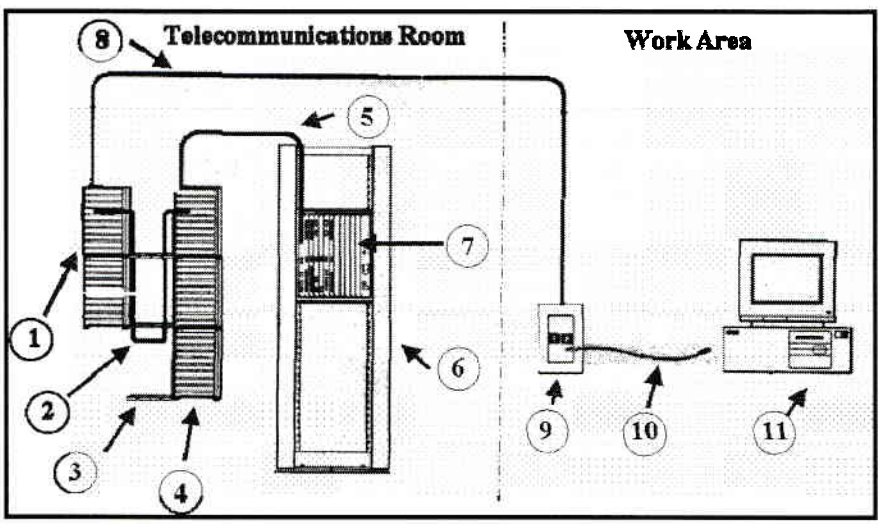
Once the quote is accepted, the installation company creates a work schedule for their staff. It is important to get started as quickly as possible, as delays to the construction schedule can be very expensive. If the installers are to place conduit this must be done before and during the initial concrete pours. In most cases the electrical contractor will be awarded the contract for the conduit, mainly because they require more of it than the telecommunication cable crew does.

Not every job is the same, but in general a cable installation proceeds in an orderly and logical fashion. In the next section, the steps below will be expanded on.

1) Placing outlet boxes on the bare wood or metal studs
2) Shape and place conduit, if required
3) Install racks or backboards in T.R., E.R. and E.F. spaces
4) Pull labelled horizontal cables from the Telecommunication Room to the outlets
5) Support cables, starting at the work area outlet
6) Label and cut cables with slack, in T.R.
7) Terminate Horizontal cables in the T.R.
8) Pull in backbone cables from E. R. or E. F. to the T.R.
9) Termination of backbone cables at both ends
10) Installation of bonding and grounding system (TIA/EIA 607)

Typically, the contract will provide for a down-payment on the work before any work actually starts, and another payment when the rough in is completed.

Figure 5-3 below shows a conceptual installation, with the cross-connect hardware and active equipment co-located in the Telecommunications Room. The names and functions of the numbered items are given below.



1 Horizontal Termination Hardware:
Termin ates 4-pair horizontal cables
One end of the Permanent Link
Provides a point of cross-connection for completing the Channel

2 Horizontal cross-connect jumpers
Extends H. Cable link to active equipment (in this case)
Extends H. Cable link to Backbone Cable link (in other cases)

3 Jumper management rings
Protects jumpers from damage or accidental disconnects
Contai n jumper cables for professional appearance

4 Main termination (or Backbone termination) hardware
As a Main Distribution Frame (MDF) terminates active equipment ports (in this case a Hub or Layer 2 Switch)
As an Intermediate Distribution Frame (IDF) terminates backbone cables in T.R. that runs to an Equipment Room located elsewhere.

5 Main Distribution (or Backbone) cable
Brings out the ports from active equipment to cross-connect hardware
As a Backbone Cable, extends the Channel to active equipment elsewhere

6 Equipment rack
Usually a 19 inch rack or free standing cabinet used to secure and protect active
or passive equipment.

7 Active Equipment
LAN equipment in this case, but may be a phone switch, router etc.

8 Horizontal Cable
4-pair Category 3, 5e or 6 cables run in a star topology to the Work Areas
Two cables are required to support the two outlets needed in the W.A.

9 Work Area Telecommunication outlet
T568A or T568B configured 8p8c modular outlet
End of the Permanent Link

10 Work Area Cord
Extends the Channel from the Permanent Link to the W.A. equipment
Stranded 4-pair cable with modular plugs on both ends

11 Active Work Area Equipment
In this case a P.C., but could be a networked printer, a telephone set etc.

G) <u>The Finish</u>

Once the rough in is completed, the cable crew has to wait until the drywalls are up and painted. This can take anywhere from a few days for a small job, to a month or more for larger structures. Once the site is ready, the installers will return and complete the installation and perform category tests on the structure. Once again this is step-by-step process.

1) Terminate and label outlets in Work Areas
2) Verification tests on permanent link basis (TIA/EIA 568.B)
3) Verification of backbone cables
4) Corrective measures as required
5) Creation of Network Documentation (TIA/EIA 606)

Verification of the cable structure can be as simple as checking continuity in a non-standard compliant cable plant, to a full Category verification test using cable scanners that will record all the tests values, production of hard copies of each cable test, and production of Administration documentation set compliant with TIA/EIA 606. These tests are generally completed well ahead of the clients' move-in date, and consequentially the building will not have be full populated by the staff, or fully equipped with all the office equipment required.

Only after all the cables are tested and have proved out will the client pay the third instalment on the contract, which still may be subject to a "hold-back" of 10% or so. This amount is to ensure that the client has enough time to determine if all the work is satisfactory. In theory, once corrective measures such as reterminating soft punches or miss-wires, or even pulling in a new cable to replace one "spiked" by the dry-wallers, there should be nothing that can go wrong. But the test of the pudding is in the tasting, and the proof of the cable structure is how it works under full operation.

Once the client is up and running a number of issues may arise, which have to be fixed. It the cables are too close to an Electro-magnetic Interference (EMI) or Radio Frequency Interference (RFI) source they will have to be relocated. Sometimes specific equipment, such as a photocopier, can send out so much interference that the LAN becomes saturated with noise and can not transmit anything while the photocopier is on. In some cases the cable company will be responsible for correcting "faults on turn-up" and in other cases the fault may lie with the client. Every cable installation company requires a good trouble-shooter who understands both the physical network and the network operating system in order to provide accurate and fair determination of the source of any troubles.

Section 5 Summary

The Design Process

Request For Quote

Bid Check List

Sizing the Structure

Estimating

Rough In

Finishing

Section 6 Cable Installation

A: The Rough In

If conduit placement was part of the bid estimate, a work crew will have to be dispatched while the cement forms are being set up. This crew will have to shape and join the conduit lengths as specified in the floor-plans. As simple as this work sounds, correct placement and sizing of the pathways is critical, as obviously the conduit can not be relocated after the concrete is laid. Fortunately, this aspect of the work is often done by a specialized crew from the electrical contractor.

1) Locate outlet boxes

- Box should extend beyond stud so it will be flush with finished wall. See Figures 6-1 and 6-2.

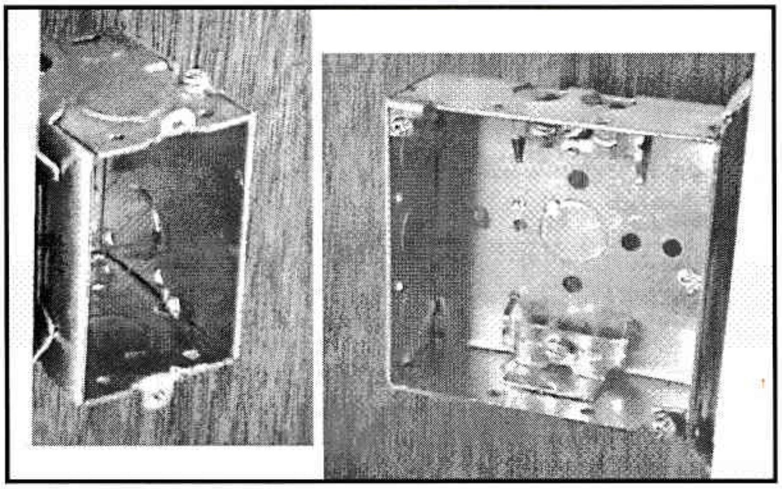


Figure 6-1 Electrical Boxes (surface mounted)

- Do not share bore holes or stud space with hydro cables or power outlets
- Do share conduit with electrical cables
- Place at same height as power outlets, or at 300 mm above finished floor.
- See Figure 6-3

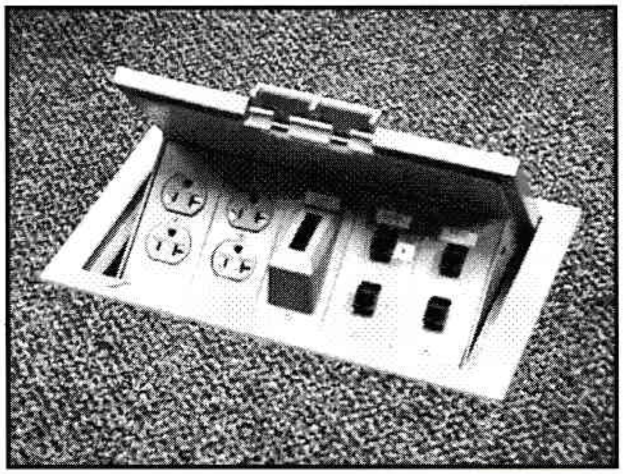


Figure 6-2 Multiple Use Outlets in Floor Mount

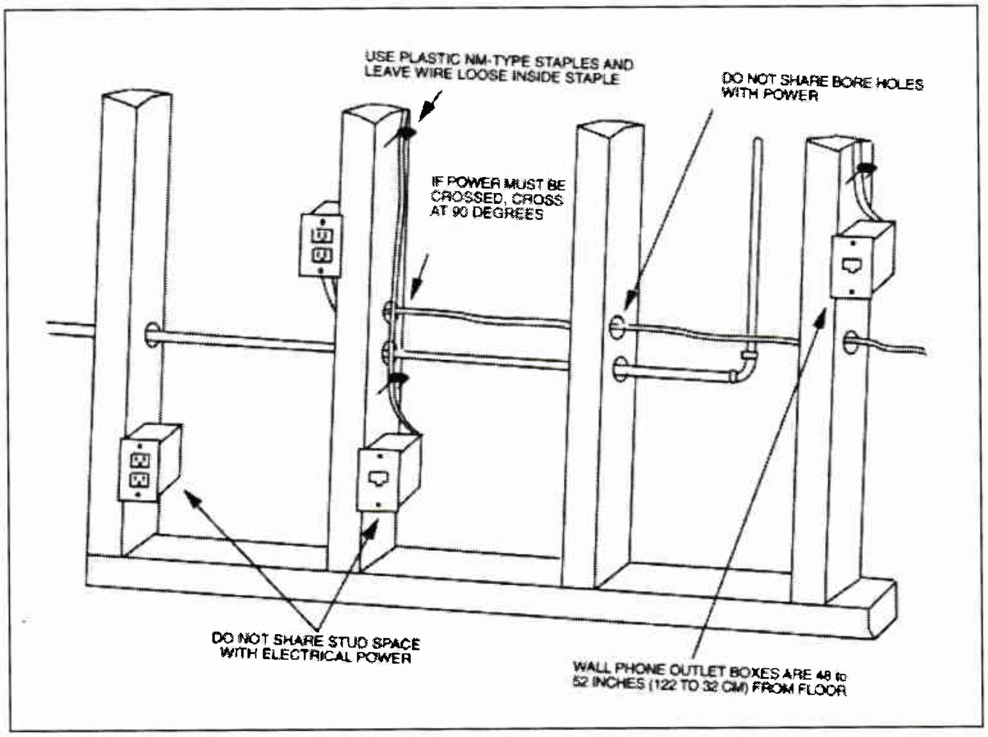


Figure 6-3 Wooden Stud Wall Treatment

2) Shape and Place Conduit, if required

- Use conduit or other pathways prepared for the telecommunications cables
- Ensure conduit ends are de-burred and will not rip the cable jackets Figure 6-4

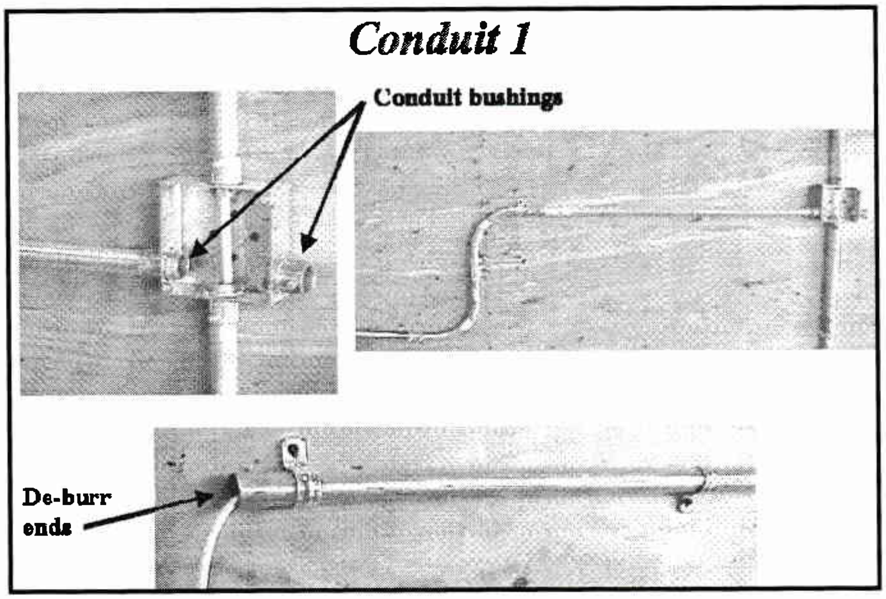
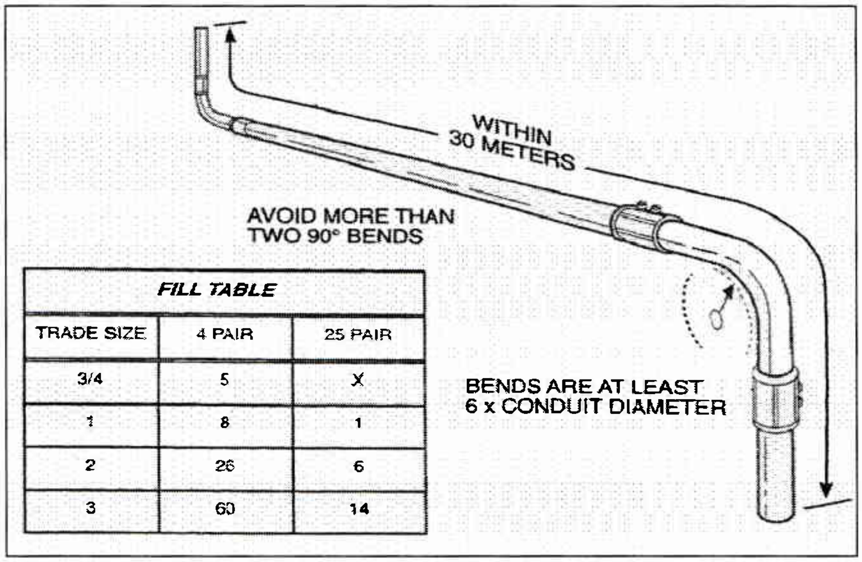


Figure 6-4 Typical Conduit Installations with Small Pull-Box

- Avoid right angle turns in boxes and sharp corners
- No more than two 90° bends in any single run of conduit
- Ensure there is a pull box every 30 meters for cable access
- Pull a pull-string into conduit when you pull in the cables
- Try to pull all required cables required in a conduit at once
- See Figure 6-4 and 6-5



FILL TABLE		
TRADE SIZE	4 PAIR	25 PAIR
3/4	5	X
1	8	1
2	26	6
3	60	14

Figure 6-5 Conduit Details

3) Install racks or backboards in T.R., E.R. and E.F. spaces

- A ¾ inch plywood backboard, with or without 6 inch standoff, as contracted
- 19 inch racks installed and secured as contracted. See Figures 6-6 & 6-7
- Horizontal cables usually enter the room through ceiling spaces (which is why these area do not normally have a dropped ceiling)
- Adequate space as defined in TIA/EIA 569 shall be provided

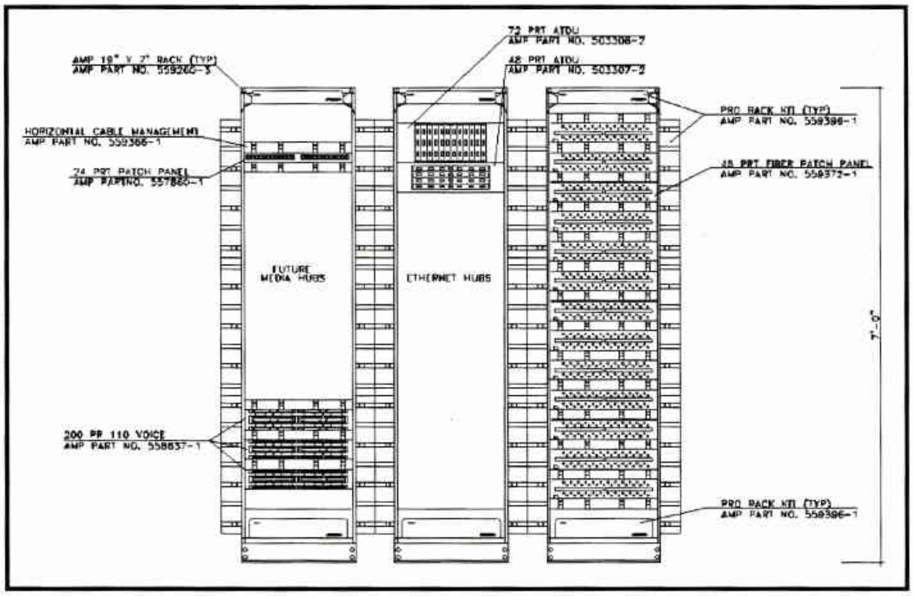


Figure 6-6 Elevation View of Rack Installation

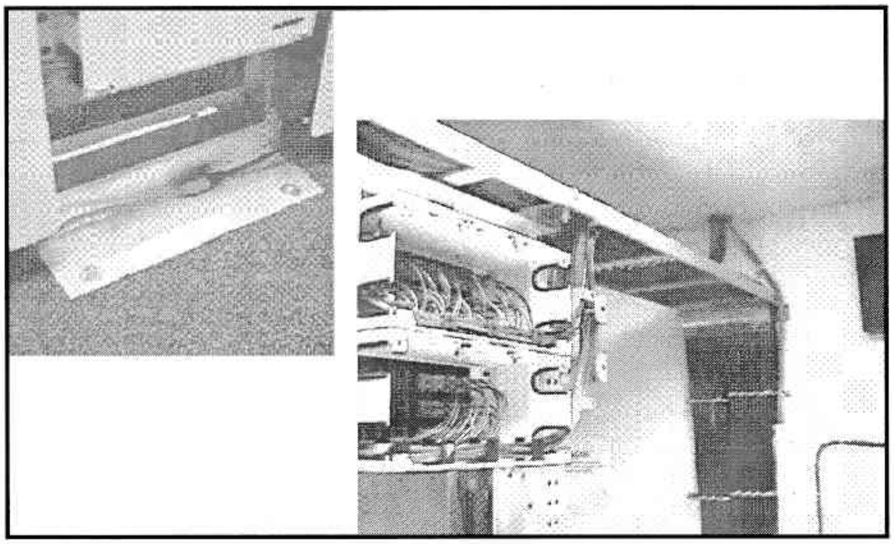


Figure 6-7 Rack Attachment and Ladder-way Cabling

4) Label and pull cables from T. Room to outlet box.

- Determine shortest route, while providing adequate separation from EMI and RFI sources. See Figure 6-8

2000 mm (6 feet) from lightning rods and conductors
150 mm (6 inches) from
Open wiring (i.e. single conductor) over 300 Volts
Neon sign wiring
120 mm (5 inches) from
Fluoresc e nt lights
Radio or CATV cables with ungrounded shields
45 mm (2 inches) from
Open wiring below 300 Volts
Teleph one entrance cables
Avoid paralleling electrical wiring
Cross electrical wires at 90° and at 45 mm (2 inch) separation

Figure 6-8 Suggested Separation Distances for UTP

- Place cable spools in T.R. and fan-out cables from there
- Sequentially label loose ends of cables before pulling. See Figure 6-4
- H. cables usually exit the T.R. through the ceiling space
- Pull to most distant outlets while the spools are full (1000 ft spools)
- <u>Do not</u> use over 25 pounds pull on 4-pair cable.
- Place any Consolidation Points at this time. H. cables can be terminated to the C.P. at this time. See figure 6-9

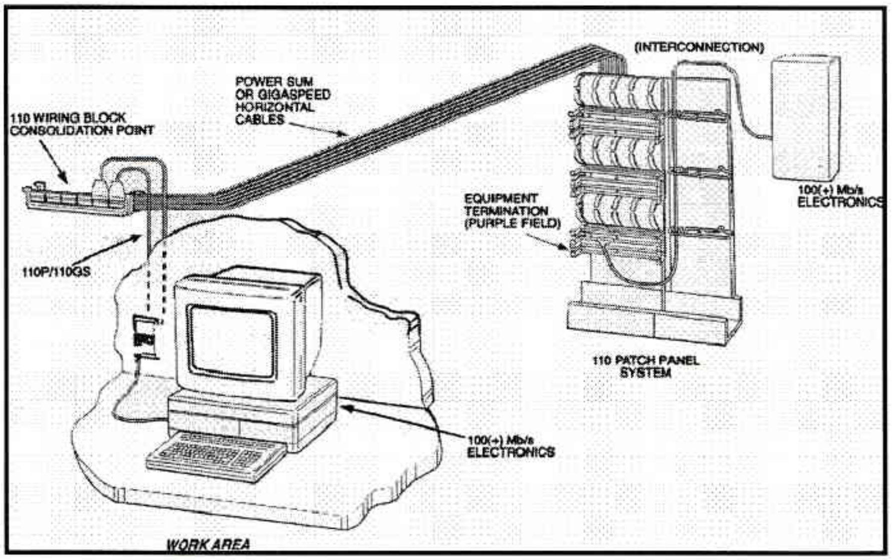


Figure 6-9 Consolidation Point on Horizontal Cabling

- Use a steady pull and do not jerk the cable but check to see what is binding.
- Maintain an adequate bend radius at all times See Figure 6-11
- Use a third person, pulleys or quadrants at turns and corners See Figure 6-10

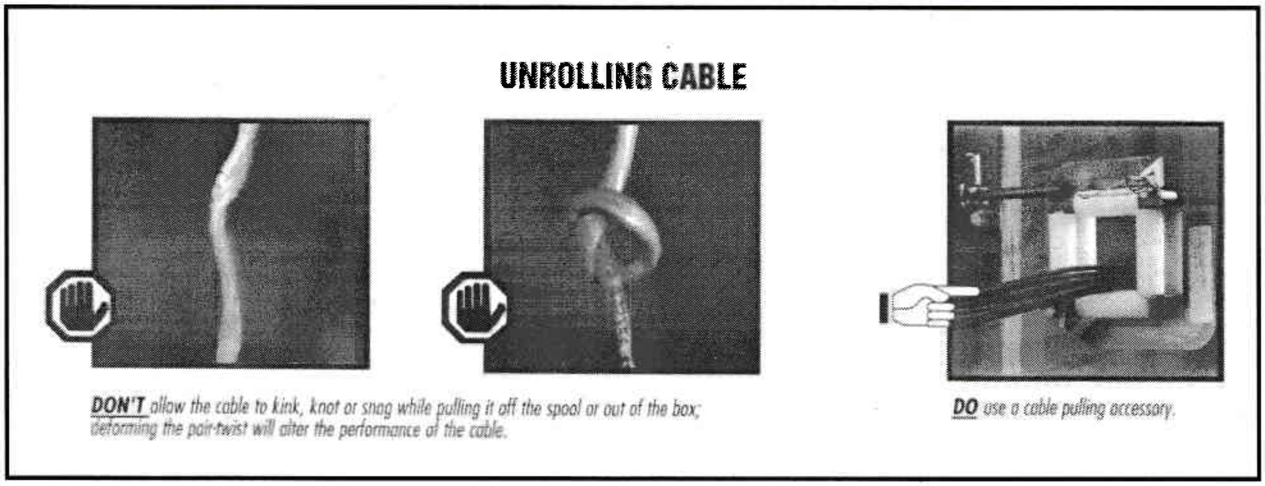


Figure 6-10 Cable Handling Practices

- Pull around HVAC and similar obstructions
- If using conduit, pull all the required cables at once, and a new pull-string
- Leave at least 1 meter slack at outlet, double for fiber optics
- Coil up the slack and place in outlet box to keep off the floor, if unable to terminate right away

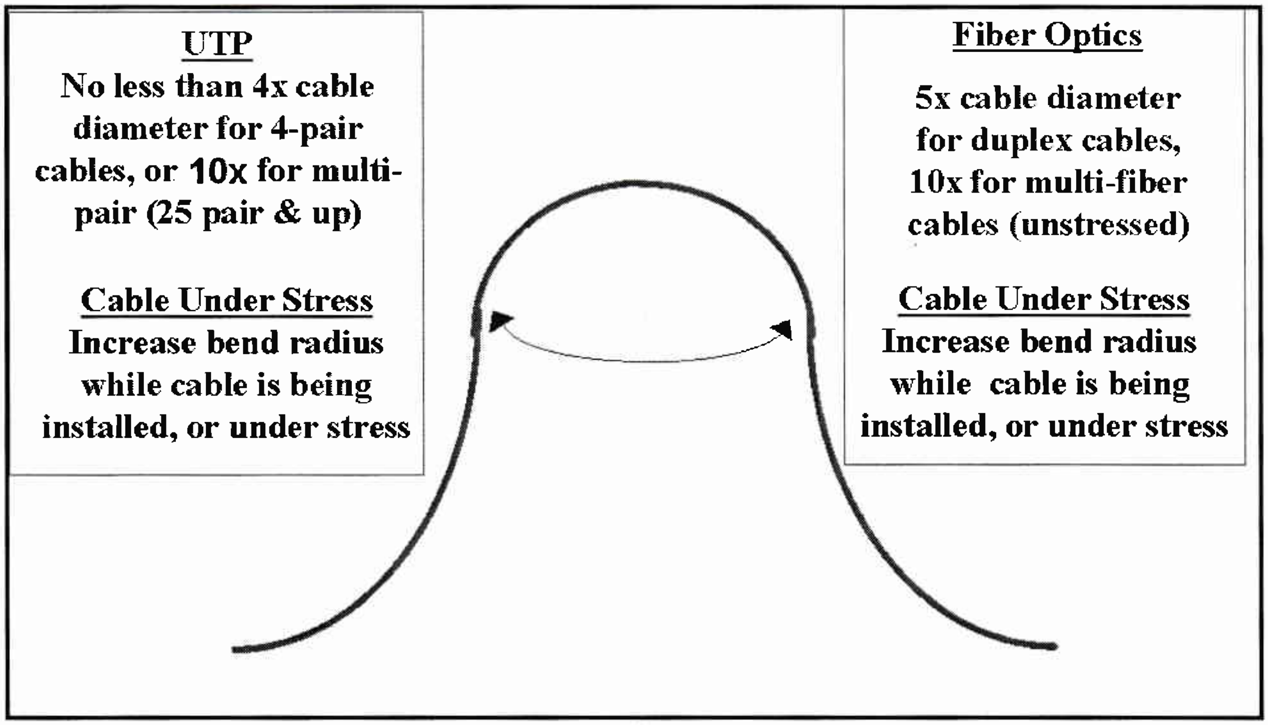


Figure 6-11 Bend Radius

5) Support cables every 1.5 meters, with no more than 300 mm 12 inches) of sag.

- Do not deform cable jackets with over-tightened cable ties. See Figure 6-12
- Use stopped staples which will not deform the cable jacket. See Figure 6-13
- Cables are loosely supported, and should be able to move in the support hangers

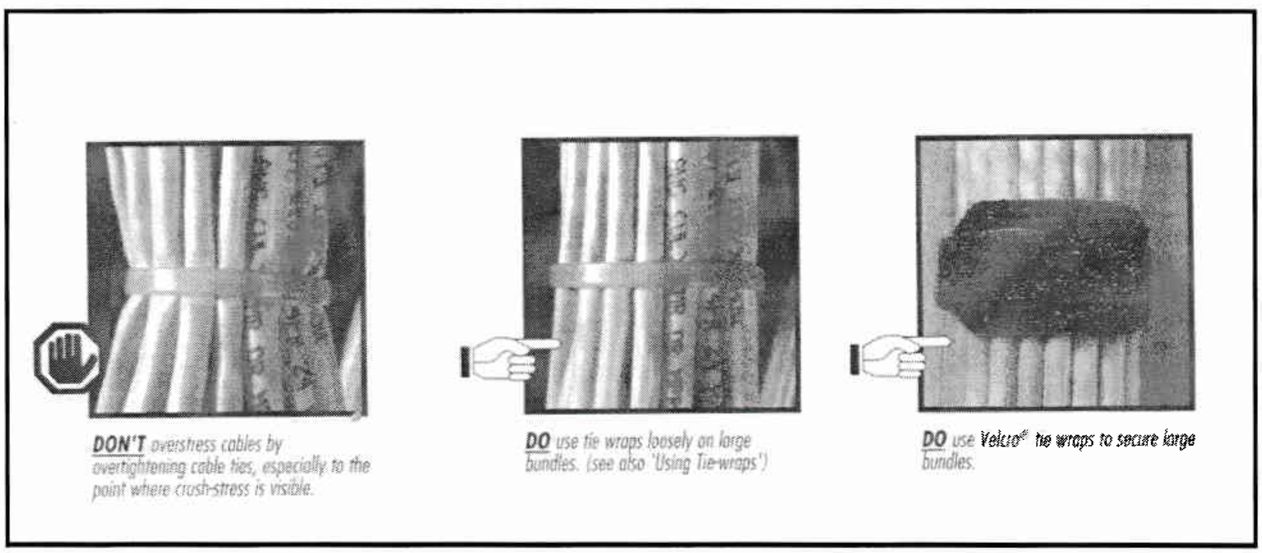


Figure 6-12 Cable Ties and Velcro Supports

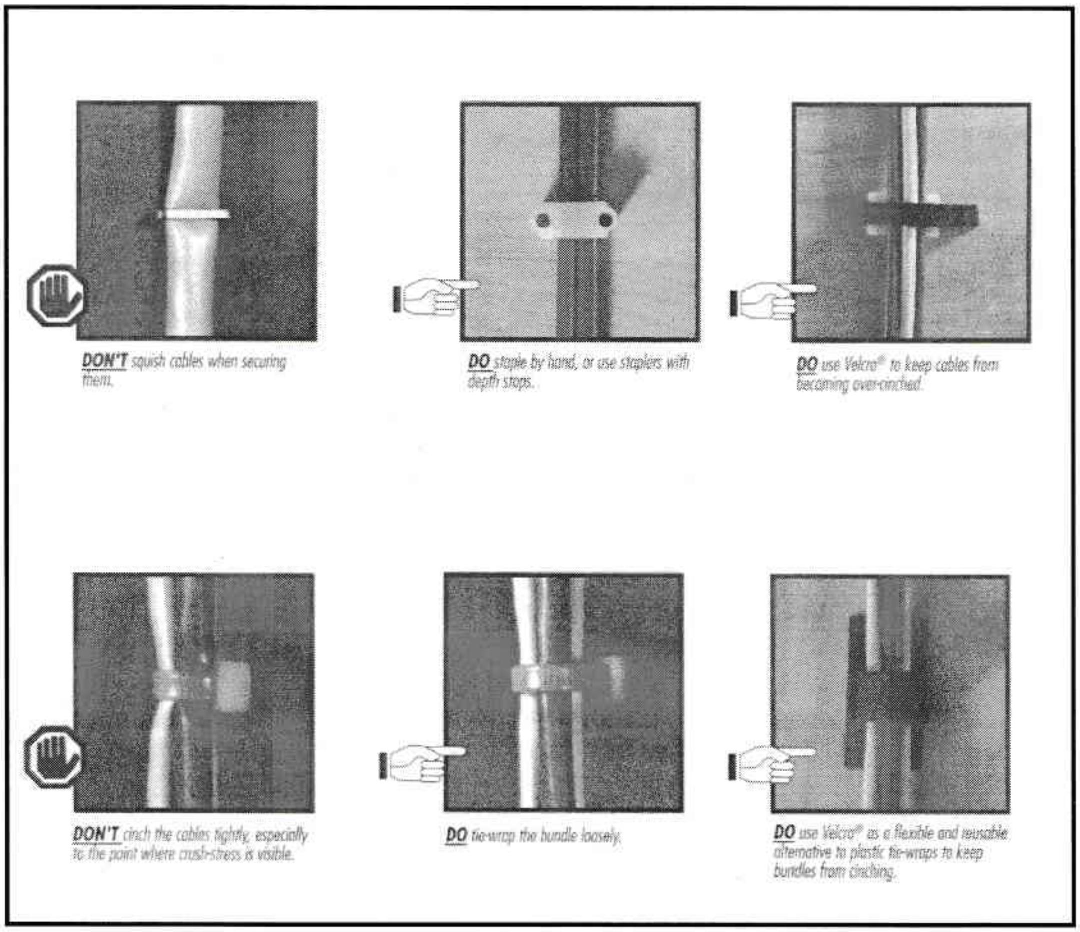


Figure 6-13 Staple and Cable Tie Practices

- Use open truss framing where available. See Figure 6-14

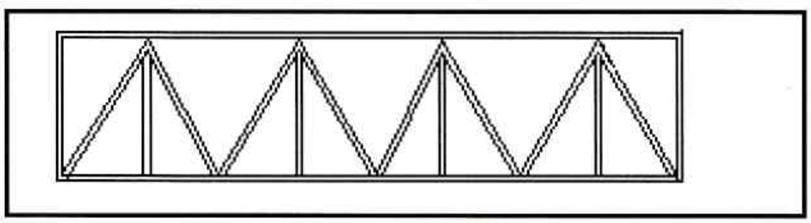


Figure 6-14 Open Steel or Wood Trusses

- Use ring hangers or "J" hooks where no other support available. See Figure 6-15

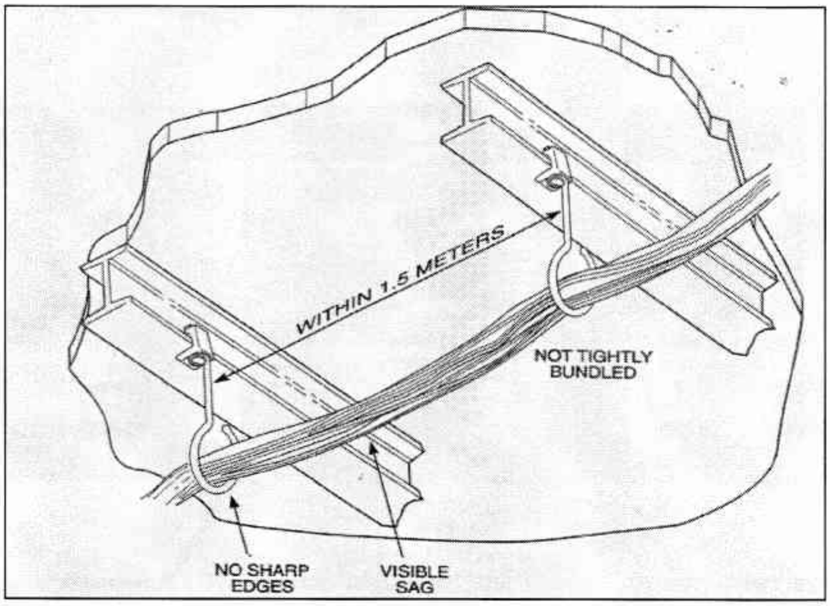


Figure 6-15 Install Ring Hangers to Steel I Beams

- Placing too many cables on top of each other may cause deformation of the bottom cables. See Figure 6-16

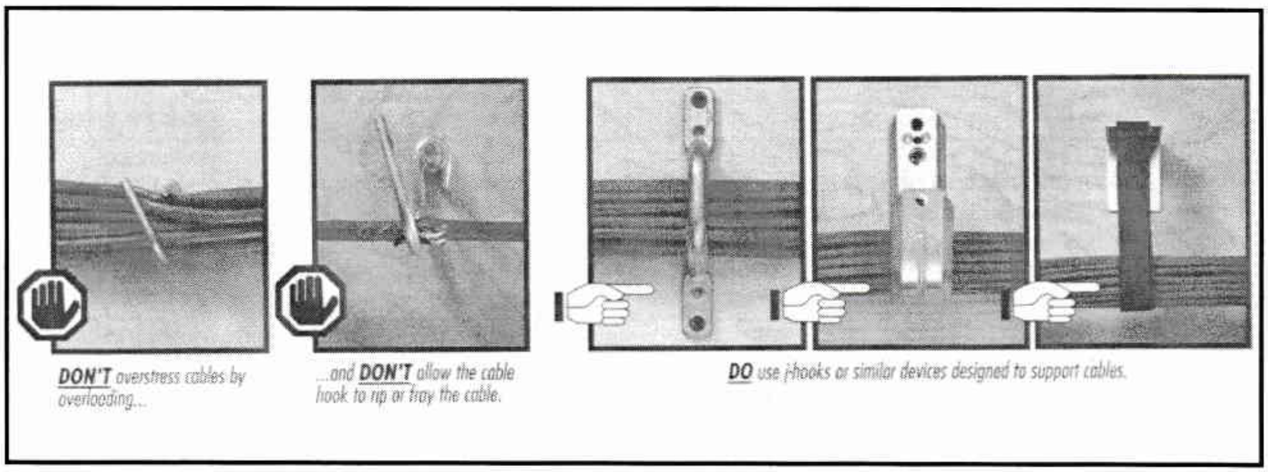


Figure 6-16 Ring and J-Hook Practices

- Do not support cables from Water lines, gas lines, electrical conduit, or HVAC structures
- Some municipalities may not permit attaching cables to ceiling tile hangers
- Do not lay cables directly onto ceiling tiles.
- Avoid firewalls and outside walls wherever possible.
- Use Cable Management equipment correctly. See Figure 6-17

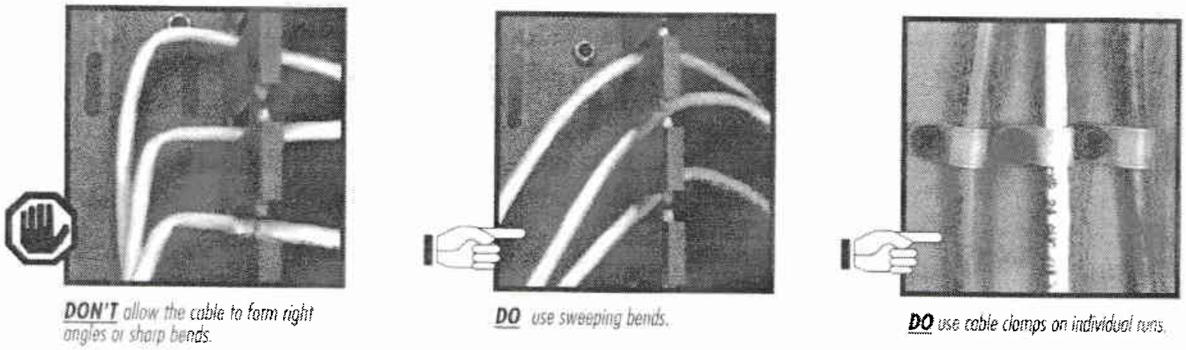


Figure 6-17 Cable Management Practices

6) Cut cables in the Telecommunications Room

- Route cables to rack or backboard area, then label cables while still in the box. See Figure 6-18 for a suggested method of keeping the labels correct
- Cut with at least 2 meters of slack.
- H. cables will be terminated in room groups, so group the cables from the same rooms in bundles and coil them up if you are not ready to terminate the horizontal cables at this time. Use electricians tape to hold the bundles together.

1) Mark each cable box alphabetically (say A, B, C, D for pulling 4 cables at once).
2) Label the outlet ends sequentially with the lowest number from the A box, 2nd lowest from the B box etc. (For example your 2nd pull will have cable 5 from box A, cable 6 from box B, etc.)
3) Pull the 4 cables to their respective outlets, leaving slack and the label visible
4) Indicate on the floor plan which cable number goes to which outlet.
5) Label each cable at the T.R. end before cutting (e.g. A = 5, B = 6, C = 7, and D = 8)

Figure 6-18 Ensure you Label the Cables Correctly

7) Terminate Horizontal cables in the T.R.

- Attach all the horizontal cross-connecting hardware to the backboard. If laying in Cat 3 and Cat 5e cables, assign two different areas of cross-connects to provide application separation
- Determine where you will be storing the slack (e.g. above the dropped ceiling, in a slack box, etc.)
- Starting with the cables from the lowest number room, terminate the 4-pair cables onto the hardware
- Label the cross-connection block with the T.O. identification scheme you will use later on in the finish stage

8) Pull in backbone cables

- Label loose ends of backbone cables
- Pull in backbone cables from E.F. to E.R. Support the cables, and label at the box end before you cut the cables
- Pull in backbone cables from E.R. to T.R. Support and label as above
- Pull in Tie cables between T. Rs. Support and label.
- Leave adequate slack at both ends and store in ceiling if no slack box provided
- If unable to terminate at this time, coil the cables in groups and tape together with electricians tape.
- Backbone cables may installed in phases.

9) Termination of backbone cables at both ends

- Attach the backbone cross-connections to the back board. Provide some separation from any other cross-connect hardware present
- Terminate the backbone cables in the same order at both ends of the run
- Terminate the backbone cables in a logical manner
- Label the cross-connect hardware with the identifiers you are using
- Store the slack in a protected area

10) Installation of bonding and grounding system (TIA/EIA 607)

- Locate the building grounding electrode or main service panel
- Following TIA/EIA 607 place run in a AWG 6 (or better) green conductor to the MTGB. An electrician may be required to connect the BCFT conductor to the service panel or electrode.
- Place a TGB in every Equipment Room, and each Telecommunication Room as contracted
- Run an AWG 6 or better to each TGB from the TMGB. Keep each run as straight as possible, and separated from any other cables. Use the conduit if provided. If joining multiple T.R.s above one another, run a single conductor to the most distant TGB, connect at that end, then strip and connect the conductor, without cutting it, to each of the TGB on the way back to the TMGB
- Label the BCFT, the TBB and TBBIBC as required in TIA/EIA 607

In a new structure, you will have to leave the site at this point as the remaining work can not be done until the dry-wallers and painters have finished their jobs. Advise the general contract or head dry-waller of any firewalls you may have had to pierce, even if you are not sure it is a firewall. Ensure all your cables are off the floor and are as protected as possible.

Verify you have run all the cables you need to. Once the walls are up pulling in cables becomes much more time-consuming and problematical. If there are any areas which may not be possible to reach later, advise your boss, and you may be asked to run extra cables to those locations, just in case they are need at a later date. Make sure you take your floor plan and temporary papers with you and keep them together until you return to complete the finish work.

B: The Finish

In a small job, a single installer may be dispatched to do the finish work, and a second may come by to assist in the tests. In larger jobs two or more installers may be sent out, especially if the work is running a bit behind schedule. Remember to gather up all your paper work from the rough-in so you do not have to chase every cable down. A good habit to form is making a blank form with Room number, Outlet Number, Cable number and Type so you can quickly keep track of the outlets. Backbone cable, by its' very nature is easy to sort out. Again the process takes the form of a number of steps, which are generally done in the following order.

1) Terminate outlets in Work Areas and label

- Terminate the horizontal cable with the correct category and colour of outlet
- Feed the slack back into the wall
- Secure the outlet on to the wall plate, with the key down
- Label the outlet with the identification you are using (e.g. Room-Plate-Outlet). Be sure your label scheme matches the one you used in the T.R.
- If any cables have lost their labels, tone out the cable to ensure you know which cable you are working on
- Terminate all outlets prior to going to the next step. Figure 6-19 & 6-20

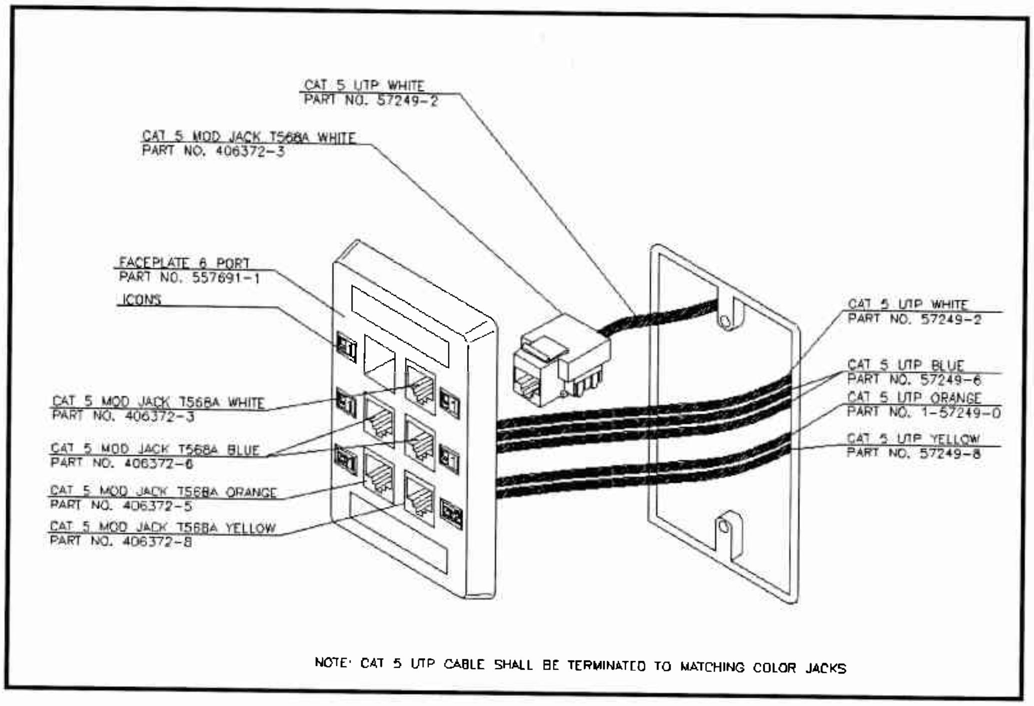


Figure 6-19 Telecommunication Outlets and Plating

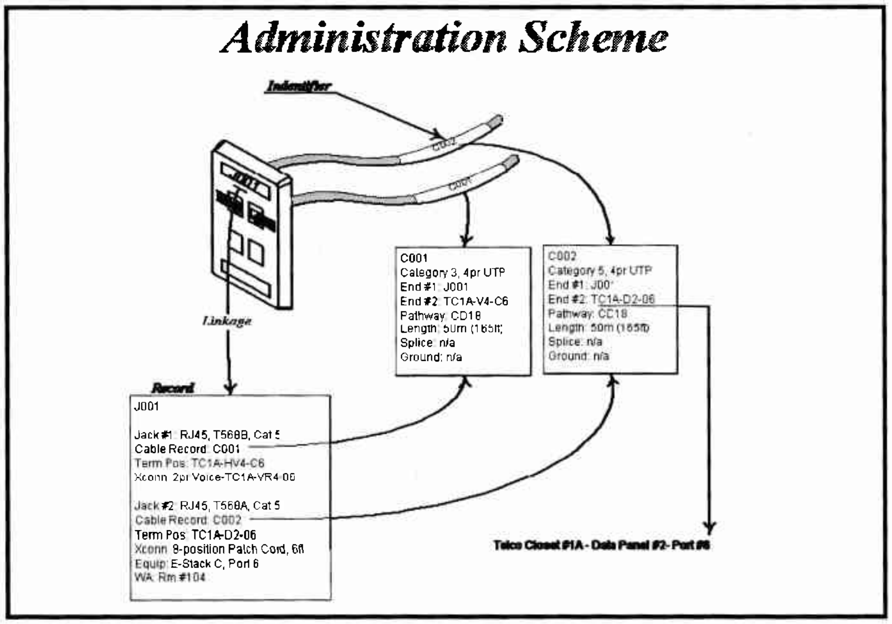


Figure 6-20 Identification for Administration Documents

2) Verification tests on permanent link basis (TIA/EIA 568.B)

- Testing goes much faster with two techs involved
- Start with the Main end of the cable scanner and one tech in the T.R.
- Use the Remote end at the outlets, and confirm all tests before moving on
- Use wireless communication or the cable scanner to keep in touch with the other tech
- Make corrective repairs for soft punches and mapping problems as you go along
- Try reterminating the outlet or cross-connect if Cross-talk fails
- Cables with lost continuity require more time. Note the cable and return later

3) **Verification of backbone cables**

- One tech in each space, normally the Head end is the room closer to the entrance cable
- Verify each set of four pairs, even if the cable is 25 pair.
- 25^{th} pair can be tested with pairs 22 to 24, or any other set of 3 pairs
- Correct any miss-wiring or soft punches before going on
- Make sure the cables and pairs are identified the same at both ends

4) Corrective measures as required

- Return to the cables which had major faults such as no continuity or impedance anomalies
- Use the time domain feature to determine the distance to the impairment
- Go to that point of the cable and visually check the cable for damage and repair if possible
- If the cable has been damaged beyond repair, a new cable has to be pulled in. Under no circumstances should you attempt to splice the cable.
- If a cable or a conductor is not repairable, record it and enter that information in the Administration Documentation

5) Creation of Network Documentation (TIA/EIA 606)

- Only create the documentation after all the cabling is installed and verified
- The documents must reflect the "as-built" structure
- Include a hard copy or softcopy of the cable tests with the client for future reference
- To be fully compliant with TIA/EIA 606 takes a great deal of time and effort, and many installation companies will leave this to the client's Network Administrator.

Section 6 Summary

Rough In Steps

Outlet Placement
One duplex box per W.A. MUTOA Placement
Conduit Placement
30 m maximum, Two 90 degree Elbows without Pull-box, Deburr
Running Cables
Label cables sequentially when pulling in
Adequate separation from Electrical Noise Sources
Support every 1.5 meters, with 300 mm sag maximums
Ensure cables can move within the supporting feature
25 pound steady pull
No Jacket Distortion
Avoid HVAC, Water and Gas Lines
Consolidation Point Installation
Bend Radius, 3rd Hands
Leave slack at both ends
Install Equipment Racks, Cable Management equipment
Terminate Horizontal Cables in T.R.
Pull in Back Bones and support
Terminate Backbones
Install Grounding and Bonding System

Finish

Terminate Outlets in W.A. and Label
All 4 Pairs terminated
½ untwist for Cat. 5e and up
3 inch untwist for Cat 3
Leave slack in stud space
Verification tests on Permanent Links
Verification of Backbones
Corrective measures to ensure all cables pass Category tests
Create Network Documentation per TIA/EIA-606 Document

Section 7 UTP Terminating Techniques

A: General Considerations in Terminations

Conductor pairs have an engineered twist to:

- Reduce energy radiation to other pairs (i.e. causing cross-talk in another pair in the cable)
- Ensure any noise induction on the conductor pairs is equal and simultaneous on both conductors (Common mode noise can be eliminated using Differential amplifiers)
- Maintain a constant Characteristic Impedance (Z_0 is determined by separation of conductors, amongst other physical parameters)

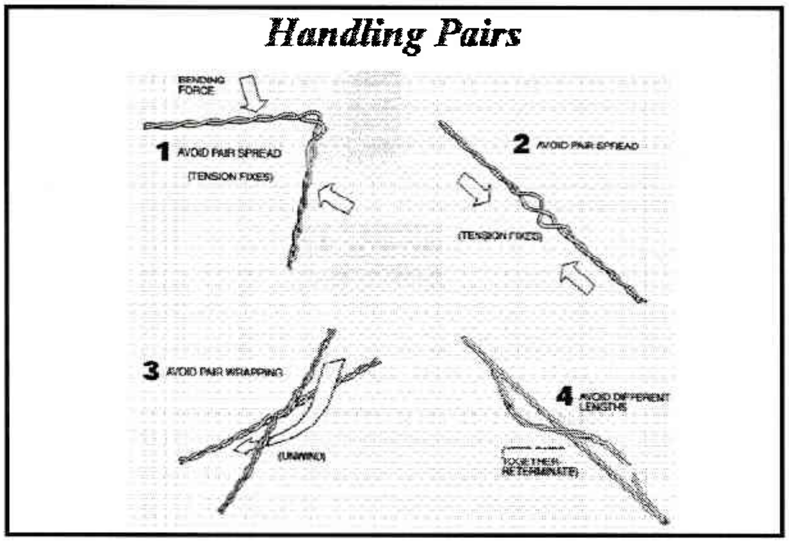


Figure 7-1 Conductor Pair Issues

The cable jacket maintains the pair twist and conductor separation and protects the conductors from insulation damage. Any deformation of the cable jacket will create an impedance anomaly which will cause reflections on the line, increase attenuation, and cause echoes and false signals.

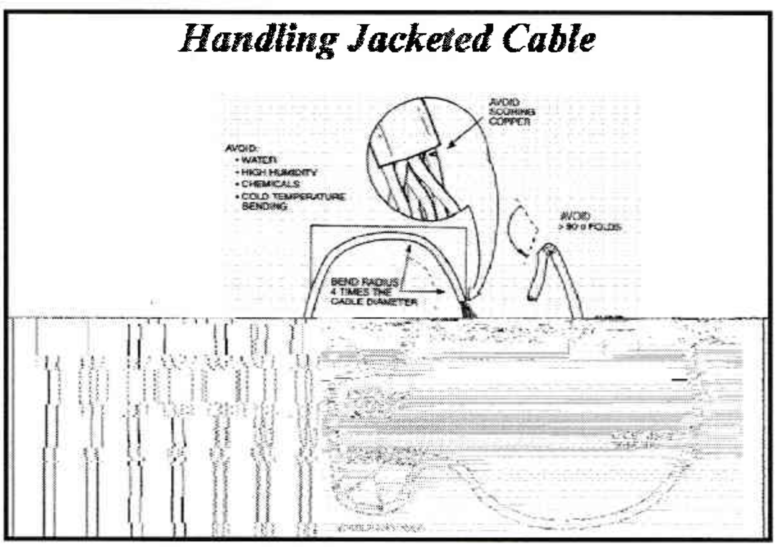


Figure 7-2 Cable Jacket Issues

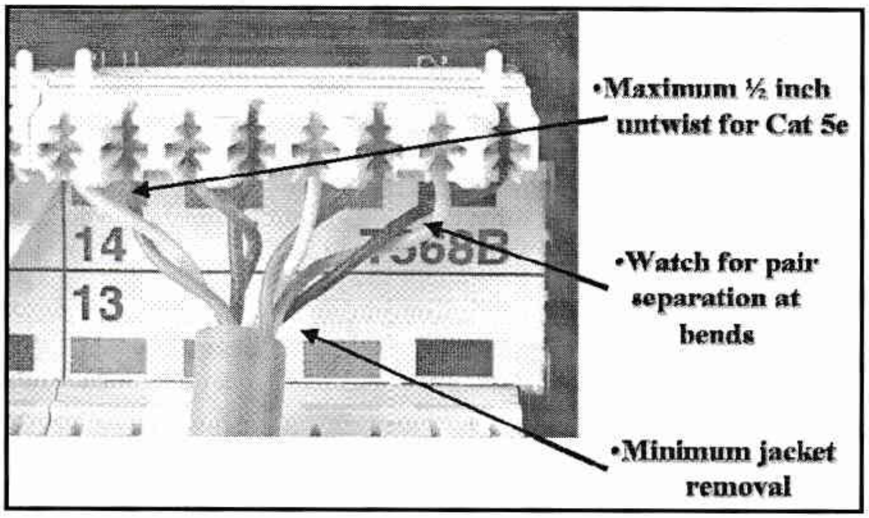


Figure 7-3 Category 5e 110-type Termination Principles

- Only remove the minimum jacket required to expose the pairs for termination
- Maintain a tight twist right to the IDC connectors
- Ensure the conductor colour codes are correct before punching

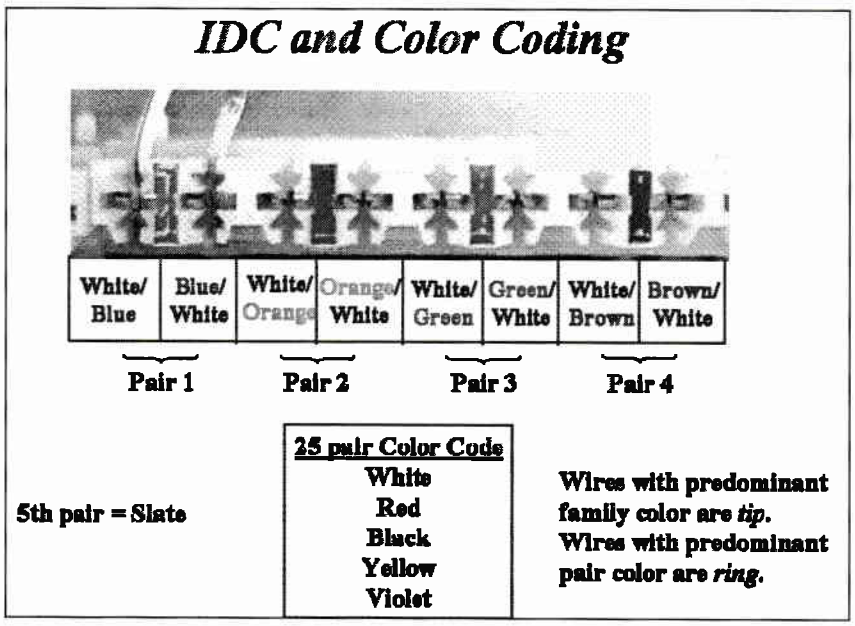


Figure 7-4 Colour Code for 4-Pair Cables

White (tips) conductors usually go to the left of the pair, but follow the colour code

B: Terminating Telecommunications Outlets

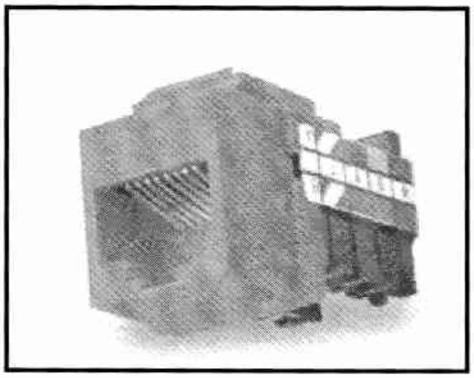


Figure 7-5 TIA/EIA Approved Telecommunications Outlet

Structured cable systems use 8p8c outlets that resemble telephone outlets (outlets). The in order to meet the requirements of TIA 568B the outlet must:

- Have 8 conductors (4 pairs)
- Have Insulation Displacement connections
- Be marked with their category rating

Most outlets will also be colour coded for T568A, T568B or both, to assist in wiring.

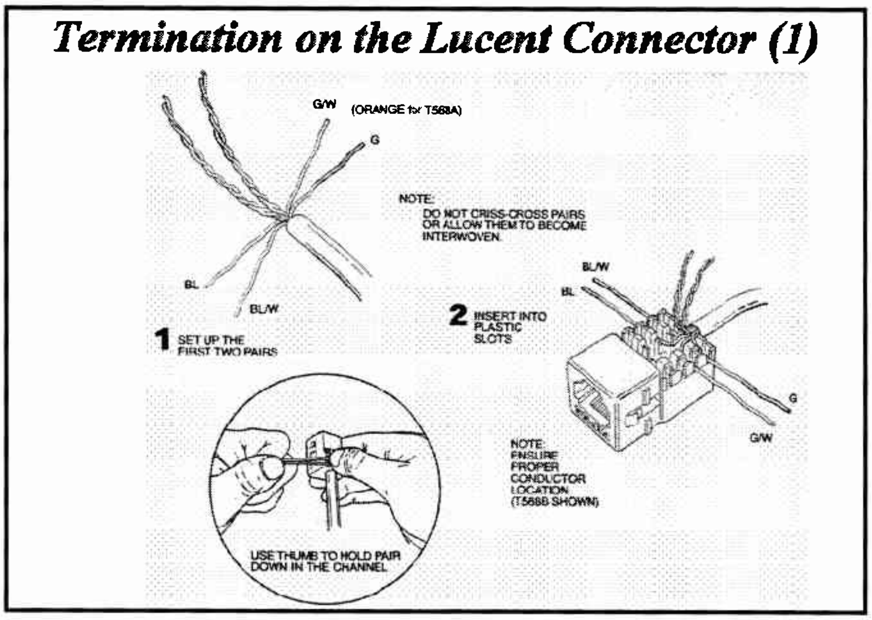


Figure 7-6 Laying Cable Conductors into IDC Outlet

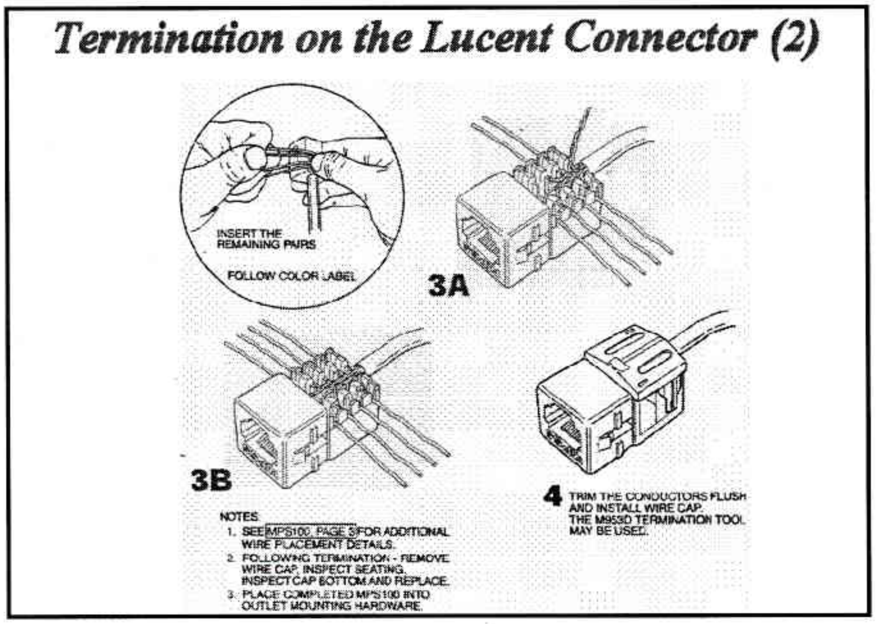


Figure 7-7 Completing the Outlet Wiring

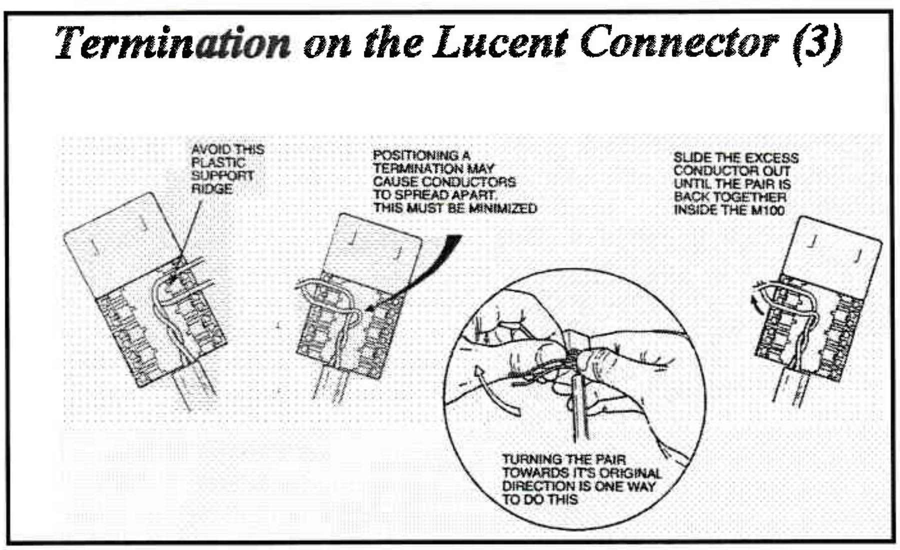


Figure 7-8 Precautions for Lucent Outlets

Various manufacturers make Category 5e and Category 6 cables. Figure 7-9, for instance, shows a similar Category 5e outlet made by Leviton.

High category outlets are constructed so that all the 4 pairs can remain twisted together right to the IDC. The conductive paths within the outlet itself are also twisted together to maintain the twists through the connector.

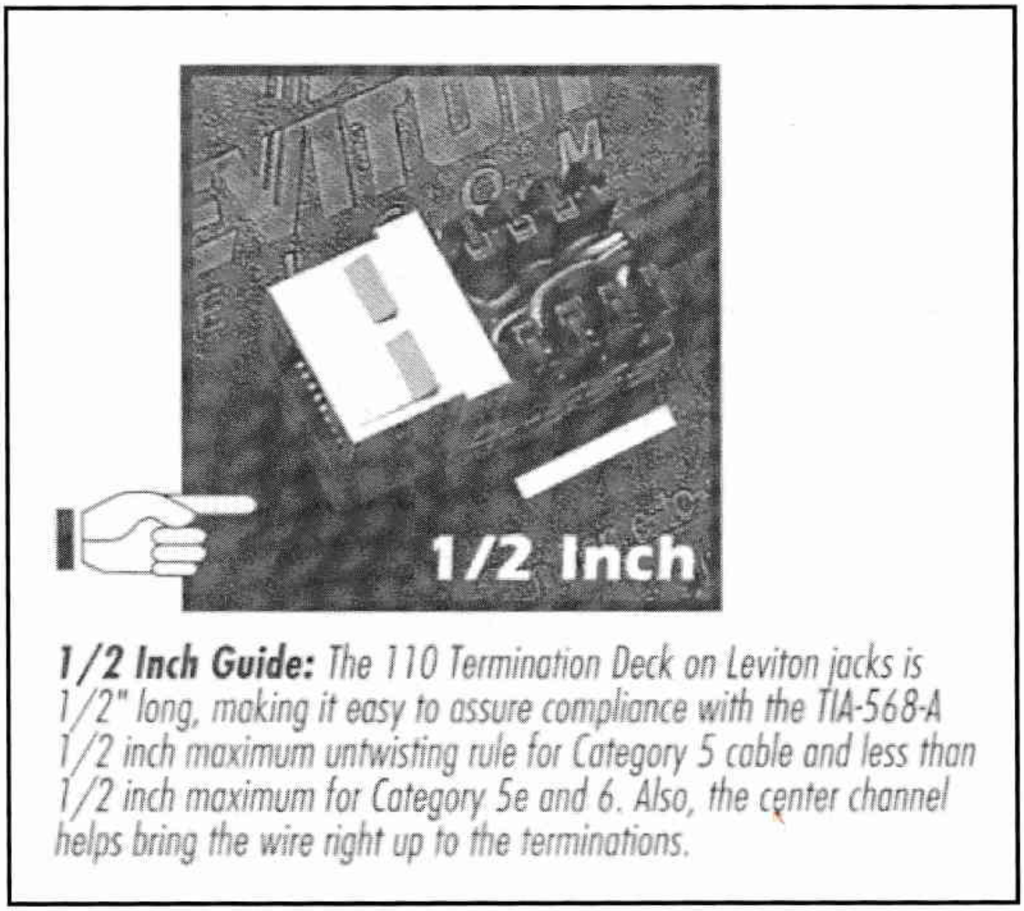


Figure 7-9 TIA-568 Outlet Summaries

C: Terminating BIX-type Hardware

BIX connectors were developed by Northern Telecom (now known as Nortel), but are now manufactured by a number of manufacturers. BIX-type connectors are commonly found in Category 3 systems used to support telephones. The QCBIX 1A rail provides a reliable interconnection point for two cables. In a typical installation the Backbone cable is terminated on the back of one rail, and the Horizontal Cable is terminated on the back of a second rail. The cross-connection is then completed by connecting jumper cables to the front of both rails.

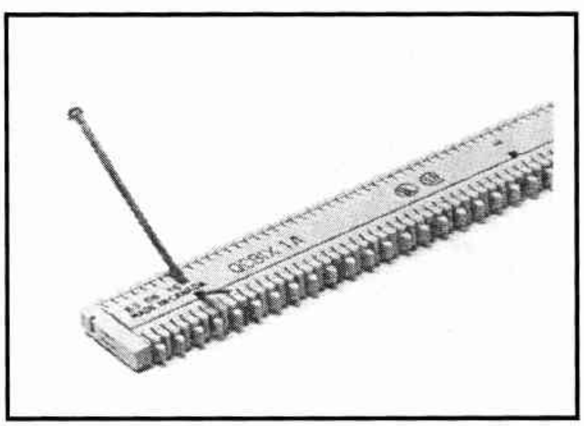


Figure 7-10 BIX 1A Rail Showing the Pair Splitter

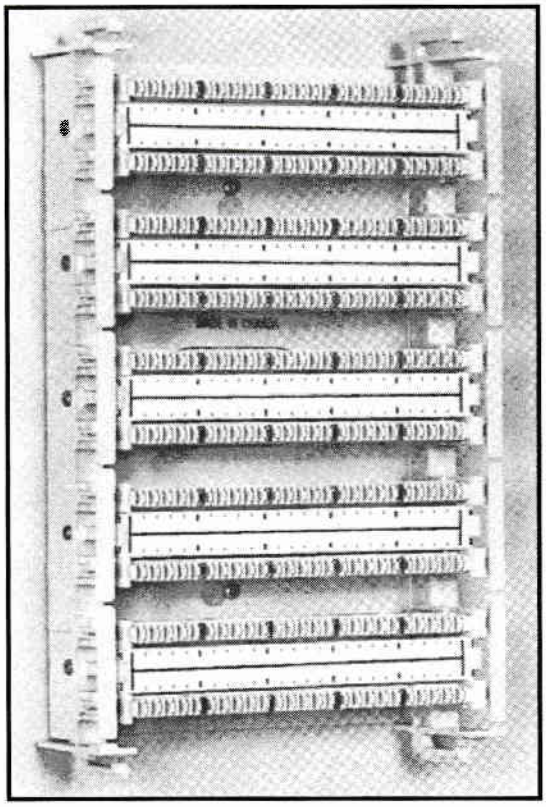


Figure 7-11 Wall Mounted BIX Rails

Figure 7-11 shows ten BIX rails in a wall mount. No cables have been attached at this point. Horizontal or Backbone Cables would be attached to back of rail (up to 25 pairs per rail). Cross-connect jumpers can then be terminated on the front of the rails, providing a cross-connection from the Backbone Cables to the Horizontal Cables.

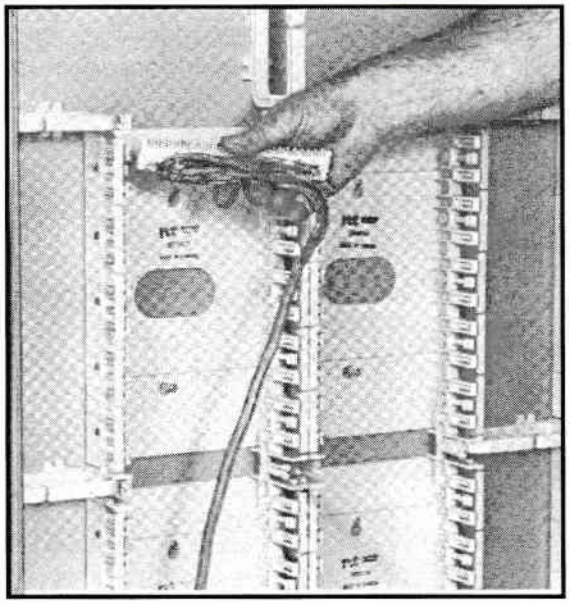


Figure 7-12 A 25-Pair Cable terminated on a BIX 1A Rail.

Figure 7-12 shows a 25-pair Category 3 Backbone Cable terminated on a 1A rail. The cable has a "hinge" of extra cable to allow for some flexibility, and to provide some slack for re-termination if required. The rail will be mounted with the 25-pair to the back, which would allow the unterminated side (the thumb side in the figure) to face outward, and be available for cross-connection jumpers.

The jacketed cable is left loose in the mount. The jumper cables in Figure 7-12 would leave the mount on the left hand side, and be managed by the cable rings (D-rings).

BIX rails come in a number of configurations including the 2A and 5A rails that allow 2 or 5 way splitters, 2, 3 or 4 pair USOC outlets, or TIA 568 type 8p8c outlets.

D: Terminating 110-type Hardware

Another popular termination type used in North America is the 110-type hardware, developed originally by AT&T. 110-type hardware can be used to terminate 4-pair, 25 pair or larger cable counts.

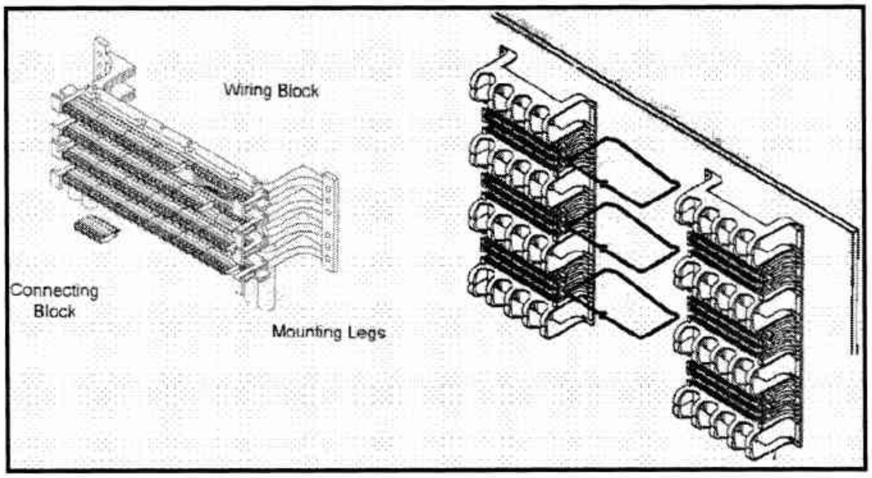


Figure 7-13 110-Type Wiring Blocks & Cable Management Blocks

110-type wiring blocks consist of a plastic index block, with 4 or 10 twenty-five pair index strips, and 3-pair, 4-pair or 5-pair connecting blocks (also known as terminating caps). The metallic IDC connectors are in the terminating caps.

- The cables are routed to the middle of the mounting block
- The jacket is removed just before the cable comes around the front of the wiring block
- Lay 3, 4 or 5 conductor pairs into the index strip. Ensure the colour code is maintained
- Cut the conductors and seat them into the index strip using a 110-punch tool
- Fit the terminating cap (observing the colour code on the cap) and punch down
- Cross-connect jumpers or cords may then be connected to the top of the termination cap

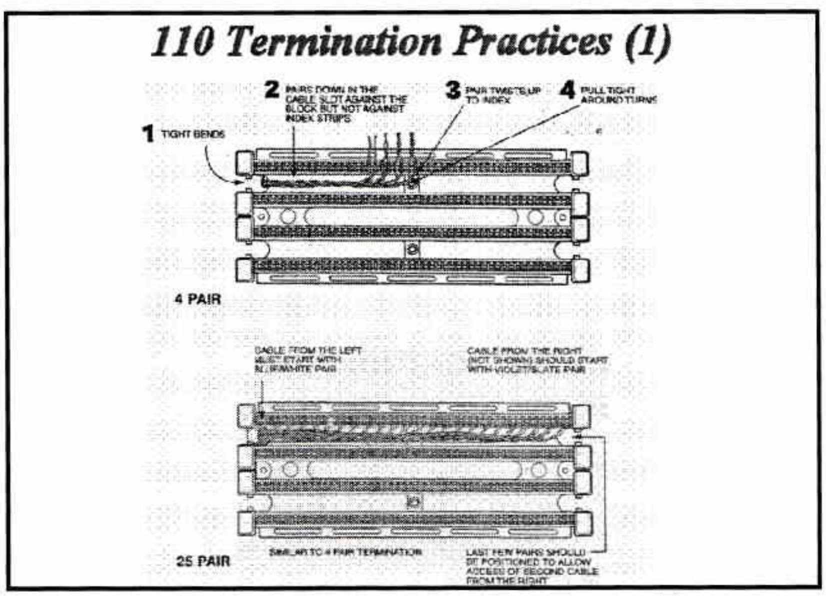


Figure 7-14 110-Type Termination Practices

Figure 7-14 shows the termination of a 4-pair cable in the upper drawing, and the termination of a 25-pair cable in the lower picture. In the case of 4-pair, each index strip will hold 6 cables, with one unused position (position 25). The first 3 pairs should enter from the left for both the top index rail and the second index rail. The last 3 pairs on the top and second rail should enter from the right. This reduces the amount of cabling crossing each other in the middle of the wiring block.

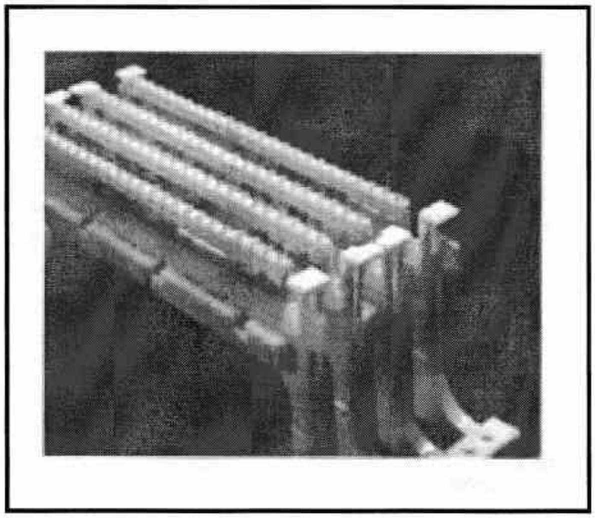


Figure 7-15 Close up of 110-type Wiring Block with Terminating Caps Installed

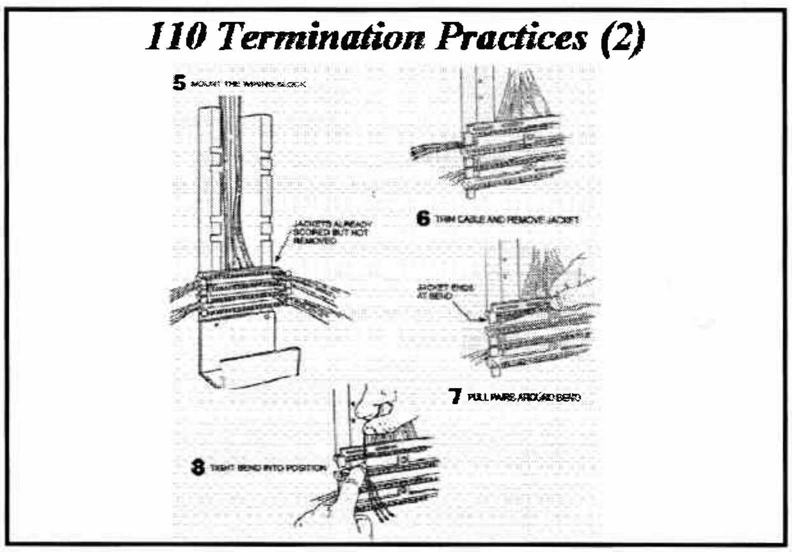


Figure 7-16 Cabling Rack Mounted Wiring Blocks with 25-Pair Cables

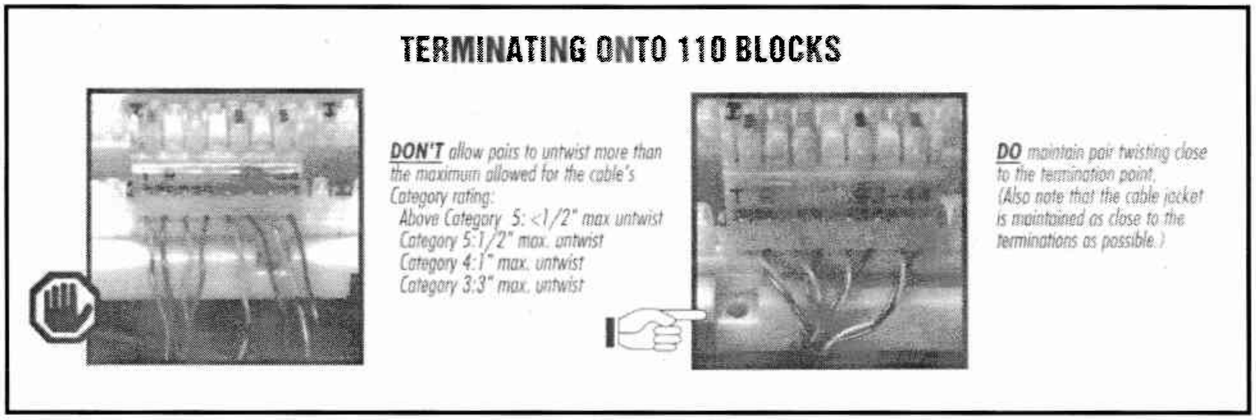


Figure 7-17 110-Type Termination Practices with Caps Installed

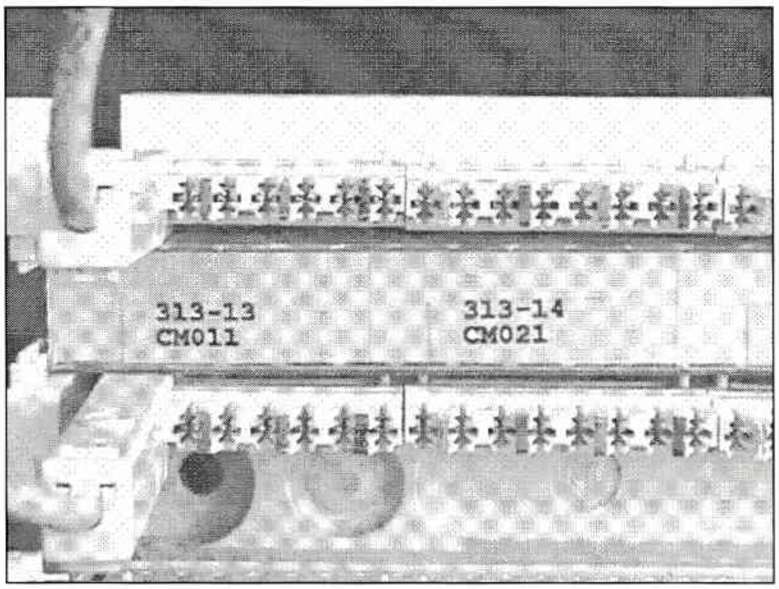


Figure 7-18 Labelled 110-Type Wiring Block, with 1-pair Jumper Cord Installed

Figure 7-18 shows the correct manner of labelling the termination block. The Horizontal Cables, which are hidden by the label plate in the photo, have been identified by the room number-outlet number (e.g. 313-13) and the cable identifier (e.g. CM011). Notice that the room and outlet numbers have taken precedence over the cable number. That is, Room 313 outlets are in close proximity, with no regard to the cable numbers.

The upper terminations in Figure 7-18 have not yet been labelled.

E: Terminating Patch Panels

Two drawbacks to both BIX and 110-type wiring blocks are that the cross-connecting cords have difficulty meeting the requirements of Category 5e and up, and they are not easily configured. The answer is to use category-rated Patch Panels that use either 110-type or BIX type connections for cable termination, but have T568A or T568B configured 8p8c outlets that allow the use of 4-pair Patch Cords.

The cables end in T568A or T568B outlets, which permit easy cross-connection using patch cords, are similar to the Work Area cords. Patch cords are made from stranded conductors so they have more flexibility, and do not require any special tools when adding or moving the connectors.

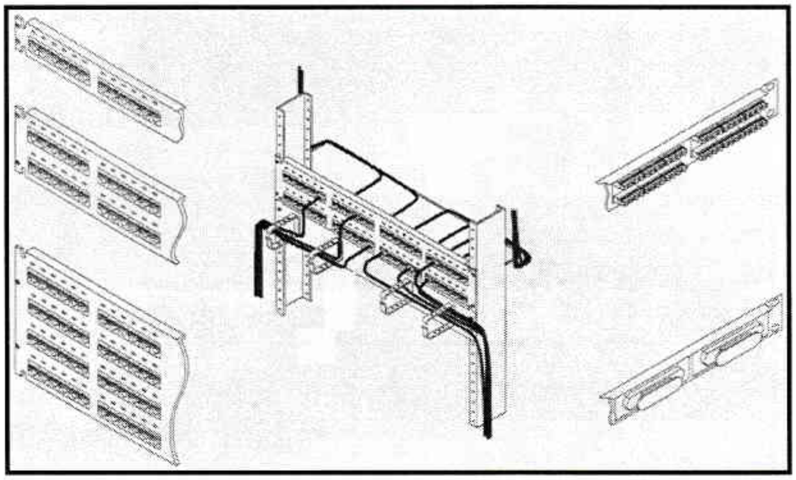


Figure 7-19 Category 5e Patch Panels

Figure 7-19 shows the front and back of a variety of patch panels as well as a method of managing the patch cords.

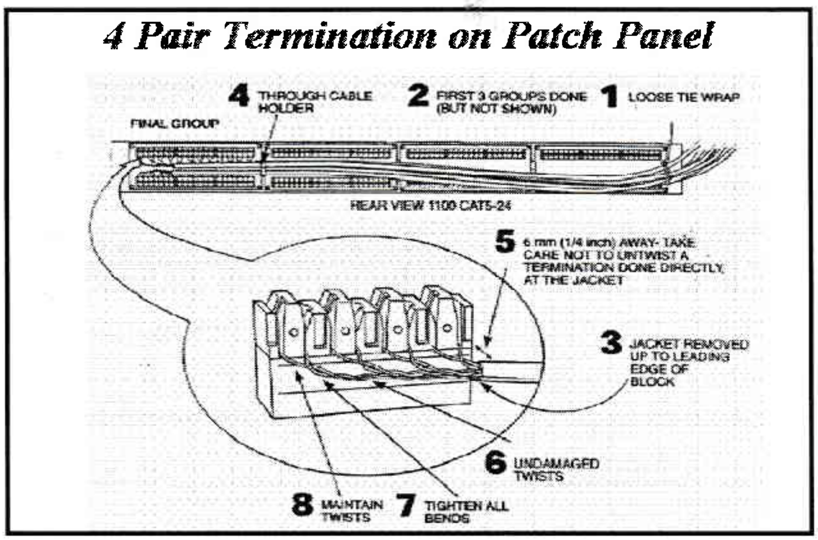


Figure 7-20 Patch Panel Terminating Practices

- Maintain cable jacket as close to the IDC point as possible
- Watch for nicks on the conductor insulators where the jacket was cut
- Maintain the pair twists to the IDC point. Always leave at least one visible twist
- Use sweeping curves to bring pair to the IDC point

- Cables are laid connected to the patch panel starting with the hinged end
- Remember to organize the cables so that outlets in the same room a grouped together
- Label each patch panel as you complete it.
- Dress cables with slack protected

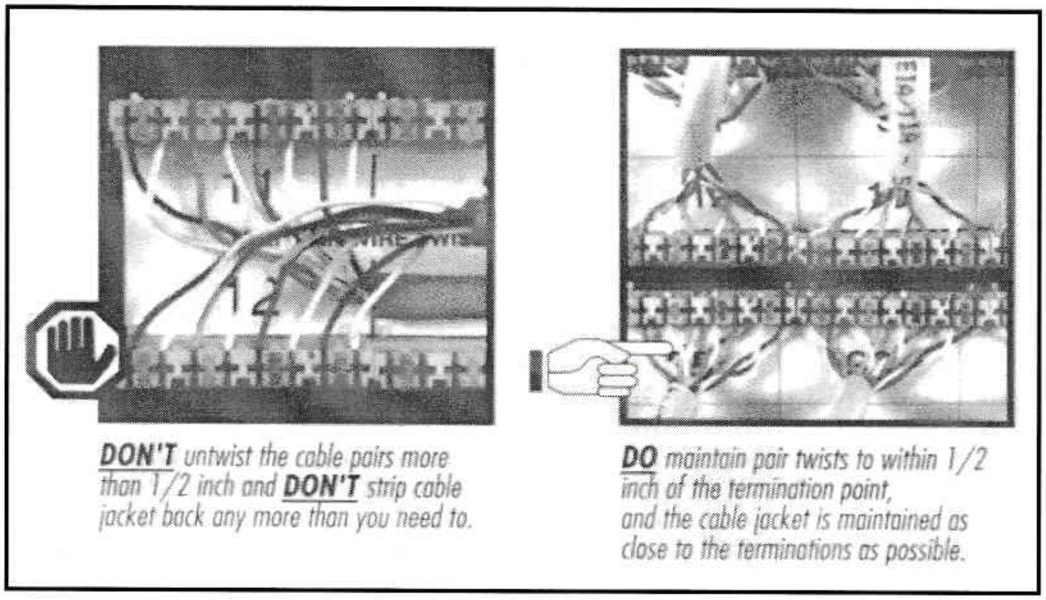


Figure 7-21 Detail Photos of Patch Panel Termination Practices.

25 Pair Termination on Patch Panel

25PAIR CABLE PAIR	1100 PANEL POSITION
BL/W OR/W GR/W BR/W	BL OR GR BR 1
SL/W BL/R OR/R GR/R	BL OR GR BR 2
BR/R SL/R BL/B OR/B	BL OR GR BR 3
GR/B BR/B SL/B BL/Y	BL OR GR BR 4
OR/Y GR/Y BR/Y SL/Y	BL OR GR BR 5
BL/V OR/V GR/V BR/V	BL OR GR BR 6
SL/V	UNUSED

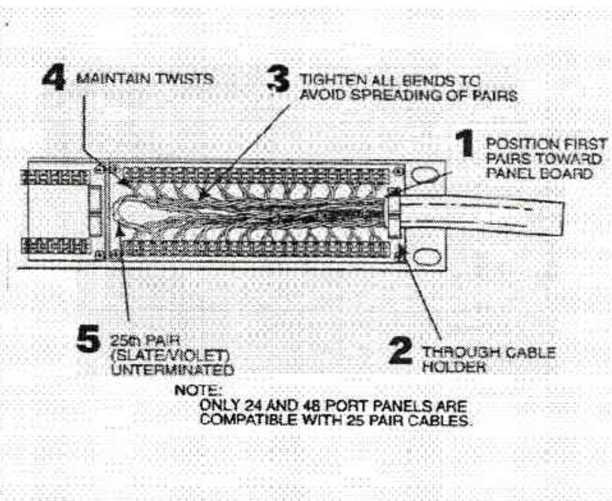


Figure 7-22 Patch Panel Termination Practice

- Cut cable jacket as close as possible to first IDC point. Check insulation for nicks
- Terminate the connectors closest to the hinge end first
- Terminate 24 pair, and turn-back (i.e. leave full length and coil up) the 25th pair as a spare
- Maintain pair twist to the IDC point
- Avoid spreading the pair, or bending too sharply where the conductors enter the IDC
- Label the outlets once the cables to the panel are terminated.

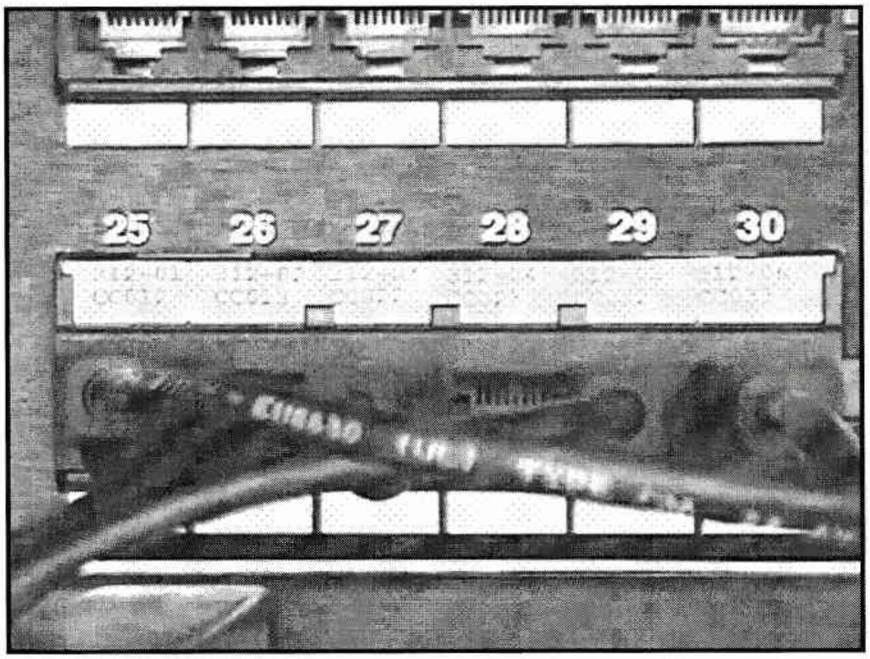


Figure 7-23 Front View of Patch Panel with Patch Cords in Place

F: Grounding and Bonding Cables

General comments

- Grounding and bonding cables have to be AWG 6 or larger, with a green coloured jacket.
- Grounding and bonding cables should be kept as straight as possible, while keeping as short as possible
- The Telecommunication grounding system should not be main grounding system for the building but in addition to it
- Splices should be kept to a minimum
- All telecommunications grounding busbars must be at the same potential (0 volts to ground)

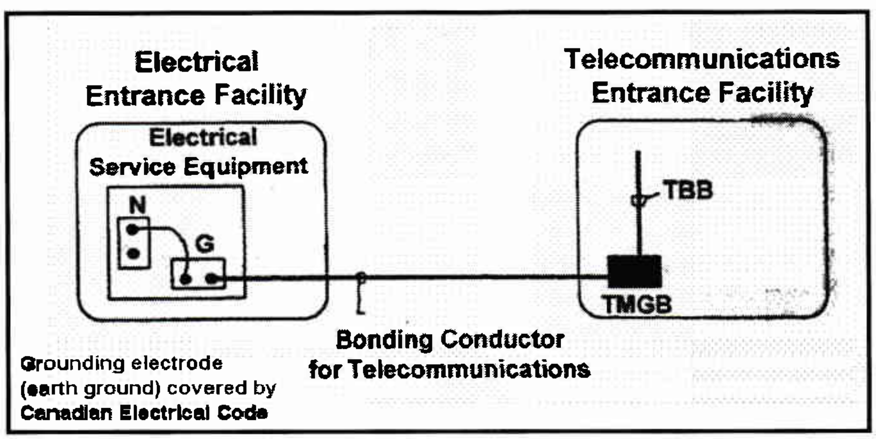


Figure 7-24 Conceptual View of TMGB Cabling

Figure 7-24 shows the BCFT and TMGB elements of the Telecommunication ground system. Here the reference ground used is from the grounding bus in the main electrical service panel for the building. This panel gets its ground from the building earth electrode, a physical metal rod driven into the ground.

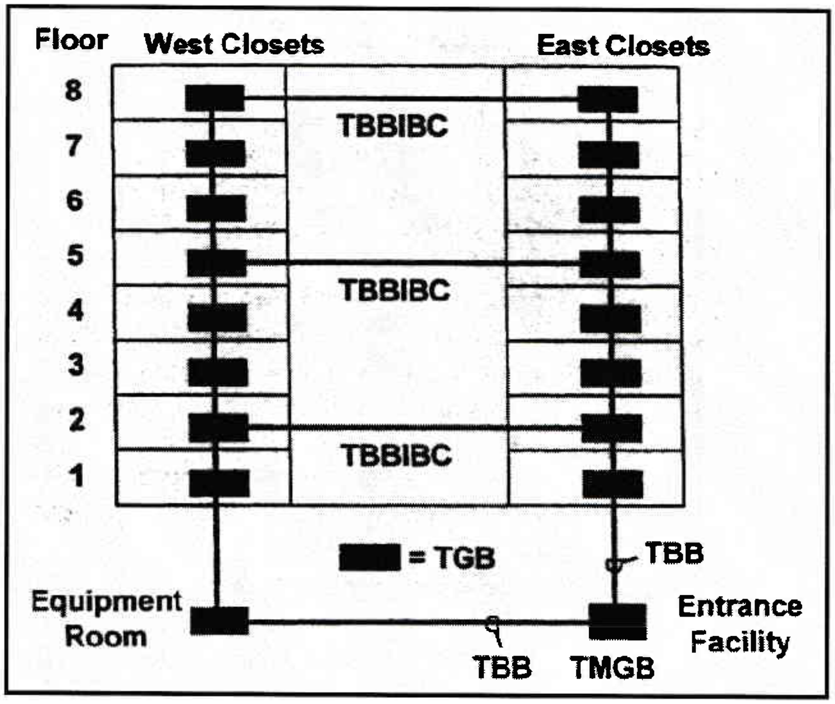


Figure 7-25 Conceptual G & B System for a Building

Figure 7-25 shows the use of the TBBIBC on every 3rd floor to provide a common ground from East to West, as well as top to bottom.

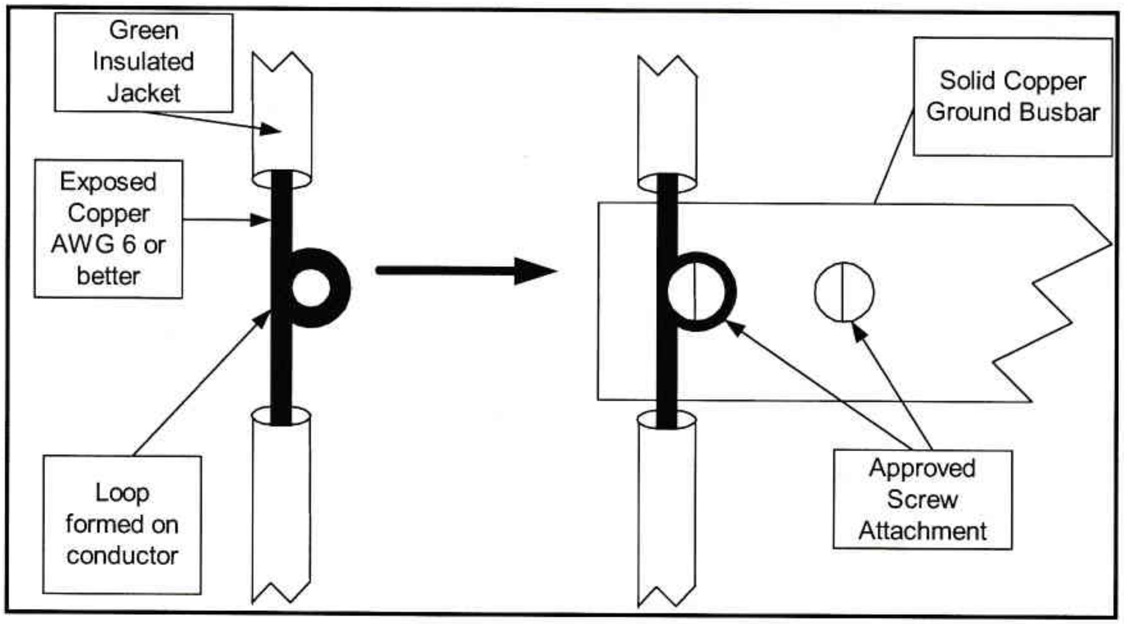


Figure 7-26 Continuous Grounding Backbone Cable Practice

Figure 7-26 shows a method of joining the Telecommunication Grounding busbars with a continuous conductor. Some jurisdictions may not allow this practice.

Figure 7-27 shows the use of separate TBB cables. This method of joining conductors is also the practice used to connect bonding conductors from the equipment to the grounding system.

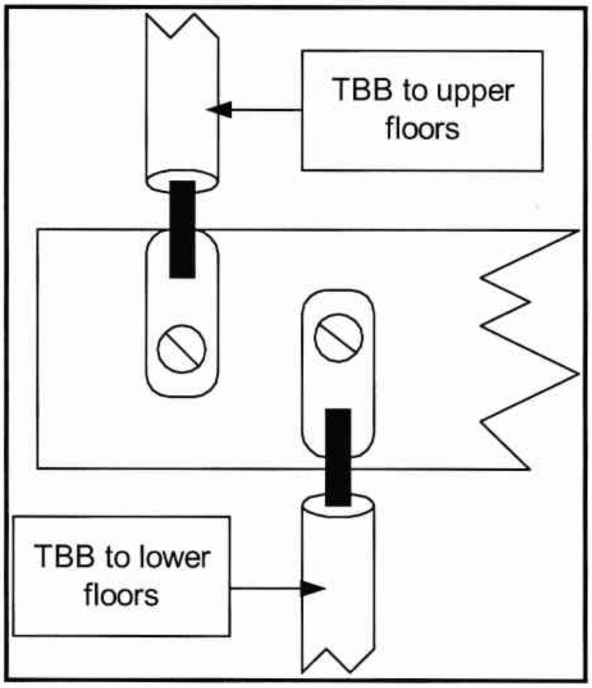


Figure 7-27 Separate Telecomm Bonding Backbones

Section 7 Summary

Terminations in General

Watch for too much untwist, cut insulation at Jacket Butt
Maintain Jacket to first IDC point
Place pair at IDC to fit twist, not twist to fit IDC
Watch for distortion, bends and knots in the cables
Use Terminations at or above Category of cable in use
Terminate as T568A unless otherwise stipulated in the contract

BIX Terminations

Cables always connect to back of rails, Jumper Pairs to front of rail
Ensure the cable has a Hinge behind the rail
Do not attach cables directly to BIX Mounting boxes
Watch for Right Angle bends into the IDC
Tip to Left, Ring to Right
Watch for Pinch Points between Rails and Mounting Box
Use the Correct Tool
Use Jumper slots for cross-connecting Rails
Install Label Plates to identify connections & cables terminated

110-Type Punch Terminations

Wire first three 4-pair cables from Left, last 3 cables from Right
Wire 25 Pair alternately from Left or Right
Butt Cable Jacket as close as possible to 1st IDC used
Watch cable bend radius coming from the back
Watch for too much untwist
Watch for Right Angle bends into the IDC
Feed cables into Mounting blocks from the centre
Use 4 pair Termination Caps for 4-Pair cables
Use 5 Pair Termination Caps for 25 Pair Cables
Install Label Plates to identify connections & cables terminated
Install Jumper Cords as Required
Used the Correct Tool

110- Patch Panels

Mount Patch Panels
Connect cable to closest Patch Panel Outlets first
Support Cables as provided by the panel
Butt Cable Jacket as close as possible to first IDC used
Watch for Right Angle bends into the IDC
Turn Back (do not cut) 25th Pair in 25-Pair Cables
Label the Patch Panel Outlets with Cable or T.O Identifiers
Used the Correct Tool

Grounding and Bonding

Use AWG6 or larger Green Conductor cable only
TMGB to Building Grounding electrode
Keep Splices on Green conductors to a minimum
Run Continuous Grounds wherever possible
Keep Conductors short and straight wherever possible

Section 8: Fiber Optics Termination and Testing

A: Theory of Fiber Optics in brief

Copper conductors have been used for telecommunication since the invention of the telegraph system in the 1800's, and its capabilities have grown from a few hundred characters a minute to today's gigabit/second networks which can transmit 7.5 characters per minute. The use of electrical impulses on a metallic conductor is a mature technology however, and further increases in speed, at least at the rate of increase seen over the last 40 years, is unlikely to continue.

Fortunately another technology is poised to take over as the backbone of telecommunications. Fiber optic systems use a light source which can be turned off and a glass fiber that carries the light pulses to a photo-detector. In terms of bandwidth and noise immunity, fiber optic systems are far superior to metallic systems.

The basic concepts of fiber optics are simple to understand at the level required by cable installers. A light source, which could be either a relatively low-speed LED (a Light Emitting Diode) or its faster relative a Laser, is turned on and off in digital fashion. These short pulses of light are guided to their destination by a two-part glass optical fiber. Although the principle of "guided light" has been known since the 1800's, it was not until the 1950's that the optical fibers were sufficiently "transparent" to carry the light with low enough losses to make fiber optic systems feasible.

The central part of these systems is the optical fiber, a thread of glass 125 millionths of a meter (125 microns) wide, only slightly larger than the width of a human hair. Like copper conductors, these glass fibers have additional layers of materials added to them to create strong, yet flexible cables. Lengths of cables can then be joined end to end, using specialized techniques, to produce a light conductor thousands of kilometres long.

To understand how light is guided in the fiber, it is necessary to understand the difference between reflection and refraction. A mirror or a highly polished metal surface can demonstrate the principle of reflection. When an incident light ray strikes the reflective surface at some angle other than 90°, a reflected ray bounces off the surface at the same angle. See Figure 8-1. A polished surface is not required for reflection to occur. This can be easily displayed by look under a table. If light did not reflect off the floor or the carpet, the bottom of the table would be in darkness. Reflections happen whenever light remains in the same material, after being "bent" back by the reflective material.

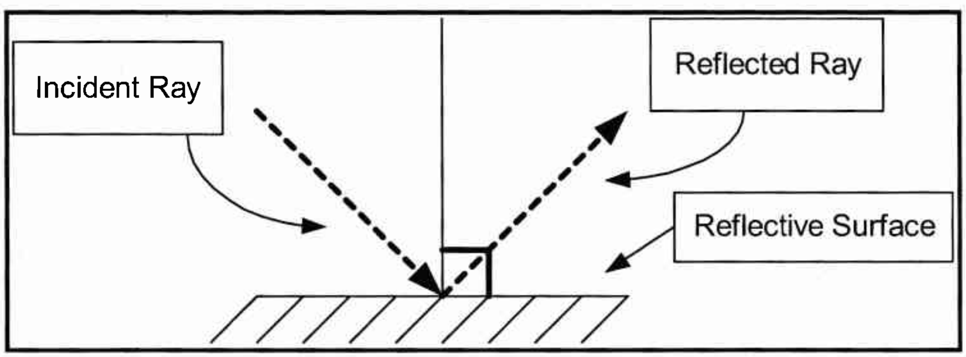


Figure 8-1 Light Reflection off a Metallic Surface

Refraction occurs when light crosses a boundary between two different materials, for example air and water. When the incident light ray strikes the boundary at something other than a right angle, a "bending" or refractive event happens. Refraction is lesser known then reflection, but we can see some examples in our common-day lives.

Have you ever noticed how a straight branch, when pushed into the water of a lake or stream, appears to bend as it enters the water? How about a straw in a glass of water? The illusion of the solid material bending is an effect of refraction. A more colourful example of refraction is the creation of rainbows by prisms and raindrops. All of these effects are a result of refraction.

The principle of refraction has been studied since the time of Newton, but it was not until the mid 20th century that inquisitive minds were able to put this principle to work for communications. Although predictions of the amount of bending has been possible for almost 200 years, if was only in the last century that scientists discovered that the amount of bending was due to differences in the speed of light in the two materials. A value known as the Index of Refraction turned out to be related to the relative speed of light in the two materials.

An analogue to the physical bending of light can be seen in the operation of a vehicle when it moves from a muddy road to a paved highway at some non-perpendicular angle. When the vehicle is on the mud road, the drive wheels tend to slip on the slick surface because of the low friction between the wheels and the mud. Pavement, however, provides a high amount of friction and the wheels will no longer spin as freely. This of course means that the vehicle will travel faster on the pavement than on the mud road, even if the engine RPM is kept constant. Let's analyze what happens when the vehicle moves from the mud to the pavement at some angle, using Figure 8-2.

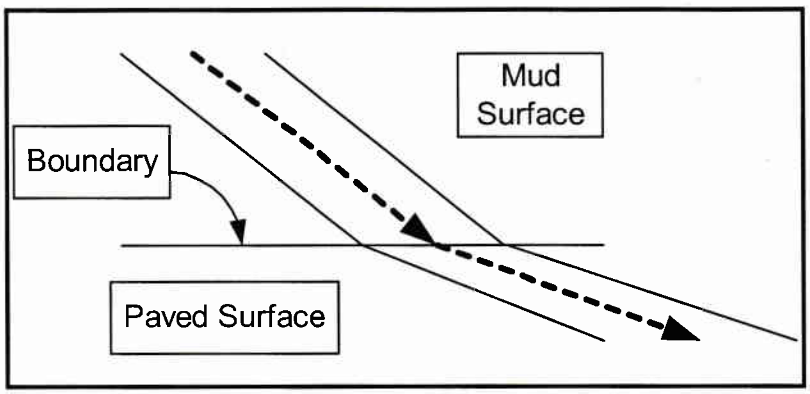


Figure 8-2 Vehicle Analogue to Light Refraction

If we say the vehicle is a front wheel drive, and approaches the mud/pavement boundary from the upper left. The wheel on the passenger side of the vehicle will strike the pavement first, while the driver side wheel is still on the mud. Consequently the passenger side will try to go faster than the driver's side, with the result that the faster side will bend towards the slower side. The steeper the angle of approach from the perpendicular, the more time passenger side has to "go fast", and the vehicle bends more.

This same model can explain why the light ray does not bend if it strikes the boundary at a right angle. The vehicle's tires now would strike the pavement at the same time, and there would be no time differential, hence no bending.

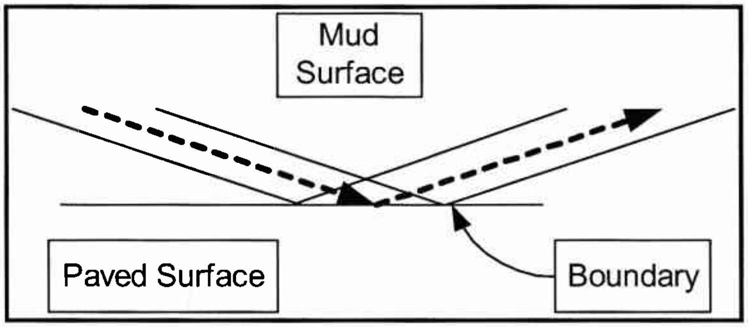


Figure 8-3 Total Internal Refraction Model

At some angle, referred to as the Critical Angle, the light ray no longer cross the boundary, but instead bends further than 90° from the perpendicular, and does not cross the boundary. The vehicle would not go onto the pavement, but in fact stay on the mud road. This effect is called Total Internal Reflection in the case of light entrapment.

The optical fiber is made of glass that has been doped so that light in the central core travels slightly slower (the mud road), than in the surrounding cladding (the pavement). When light is launched into the core at an angle greater than the critical angle, the light will stay in the core, either travelling directly down the centre of the core, or reflecting onward every time it strikes the boundary with the cladding. The light is thus contained and guided by the core and cladding of the optical fiber from its source in the LED or laser to a photo-detector, where the light is once again changed into electrical pulses.

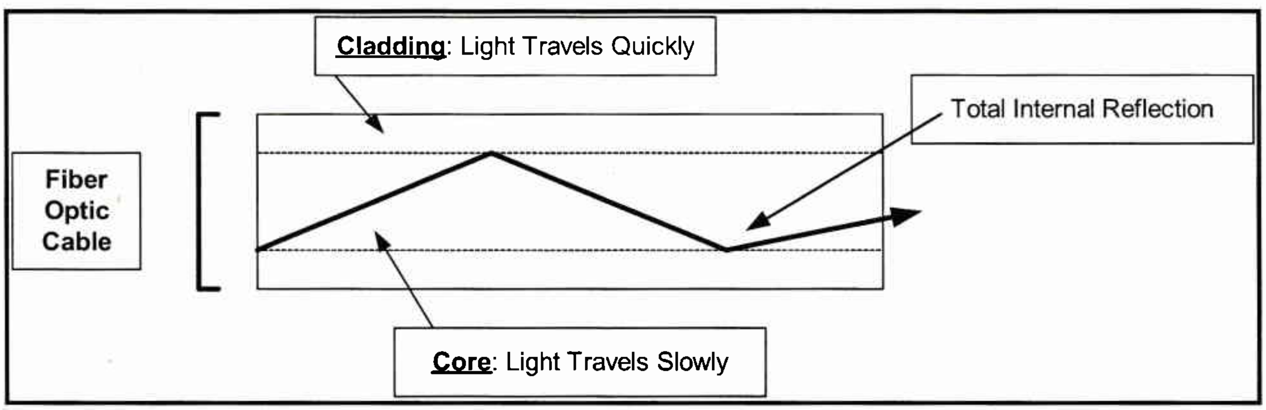


Figure 8-4 Total Internal Reflection in a Fiber Optic Cable

Optical fibers for telecommunications purposes are either single-mode or multi-mode, with the only major differences between the two being the size of the core. A single-mode optical fiber has a very small core of 8 microns in diameter, which is not much larger than the wavelength of light used, (1.300 to 1.55 microns). Like a single lane highway, single-mode optical fibers restrict the light to a single pathway, which all light must take in order to reach the far end.

Multi-mode optical fibers have larger cores of 50 or 62.5 microns in size. This larger size permits many modes, or paths of travel. As a result a ray travelling directly down the core has less distance to travel than a ray which is close to the critical angel, reflecting back and forth off the boundary. If we imagine a pulse of light being launched into the end of an optical fiber, some of the light energy will take the shorter path, and arrive at the far end quicker than the light energy that took the longer, reflective paths. As a consequence, the light pulse will lengthen, suffering an impairment called modal dispersion, an effect which increases with the distance the light has to travel in the multi-mode optical fiber.

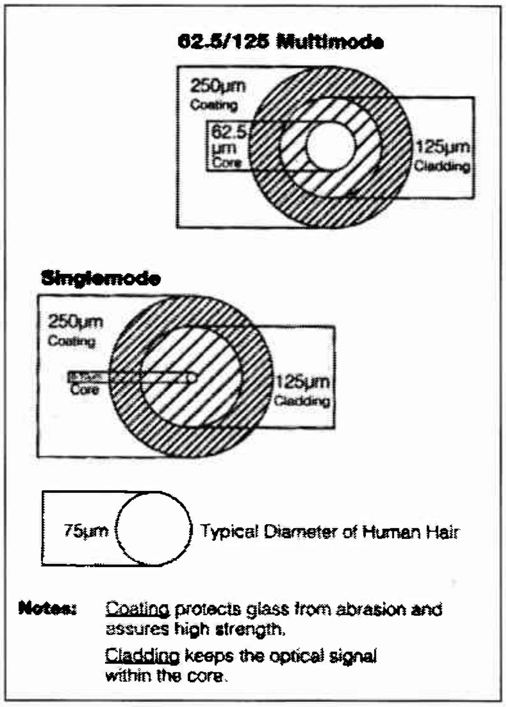


Figure 8-5 Optical Fiber Construction

This effect of modal dispersion limits the speed at which the light source may be turned on and off. A single-mode optical fiber does not suffer the same impairment, and the light pulse will reach its destination at approximately the same size as it was sent. This difference means that single-mode optical fibers are capable of sending signals at a much higher rate than multi-mode fibers can.

An obvious question is "why bother with multi-mode fibers?" As with many things, it boils down to cost. Single-mode fibers require laser sources to reach their highest speeds, and lasers are much more expensive than LED sources. A second reason is that the multi-mode, although slower than single-mode can still reach speeds of 1.6 gigabits per second with cables of 100 meters, which is substantially greater than copper UTP can reach at this time.

Additional benefits of fiber optic cables include:

- An immunity to electro-magnetic interference and radio frequency interference, which means that optical fiber systems have far fewer bit errors than copper
- A lack of radiated energy, therefore are more secure from "eavesdropping"
- A smaller physical dimension when compared to copper cables of equal capacity
- Do not conduct electricity and are therefore useful in explosive environments
- A lower attenuation, and therefore need fewer regenerators than an equal distance of copper

Structured cable system standards permit the use of either single-mode or multi-mode for backbone cables, but only allows multi-mode for the horizontal "fiber to the desktop" applications in the current documents. In the larger world of WAN networks, single-mode optical fibers dominate due to their extremely high data rates (in the trillions of bits per second).

Fiber optic cables may form the channel of a LAN structure using Horizontal cable, outlets, work area and equipment cords. When used for this purpose all the optical fibers have to be multi-mode, the same physical size, and preferably from the same manufacturer. Backbone cables may be either single or multi-mode fiber optic systems.

In order to provide a physical path from the source to destination the cables and cords must be connected in some manner. When a disconnect connection is required, the two optic fiber ends are fitted with two connectors, which are brought close together and aligned by a barrel connector. A number of different connectors are used, but the required connector in TIA/EIA-568B is the 568SC-type connector.

Where a permanent connection is required, a fusion or mechanical splice is permitted in Backbone cables and in certain circumstances with centralized cabling, as described in the TIA/EIA 568-B3 document, summarized later in this section. See Figure 8-6 for a conceptualized fiber optic backbone. Permitted attenuation for connectors, splices and lengths of optical fiber are also given in TIA/EIA 568-B3.

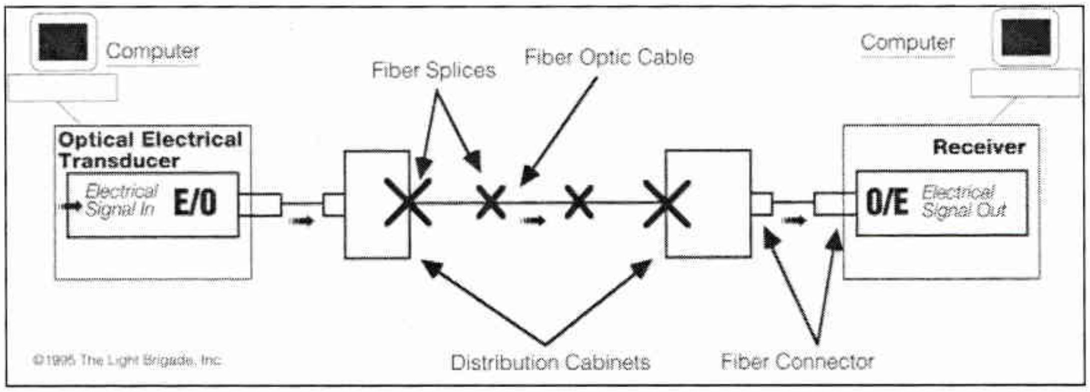


Figure 8-6 Fiber Optic Backbone Components

B: Special handling considerations

Optical fibers are glass, and like a window pane, may be easily broken by a shock, such as a drop, or even a scratch. A spool of fiber optics cable should be inspected on delivery to ensure none of the fibers in the cable are broken. This check may be done with a regular flashlight, LED or Laser light. Both ends of the fiber optic cable are accessible for this test.

Bend radius for fiber optics is also increased. In the case of the optical fiber, too severe a bend will permit the light bends to approach the core-cladding boundary at a steep angle, and some of the light will escape to the cladding and be lost (attenuated). Additionally, a severe bend, when combined with stress, can physically break the fiber, causing a total loss in light energy.

Dirt is the natural enemy of optical fibers. The particles in tobacco smoke, for example, when on the face surface of a connection can increase the connector's attenuation greatly. The reasons for this are two-fold; the smoke particle will absorb some of the light energy which increases the losses, and by holding the two end faces further apart some of the light energy will escape at the connection.

Supporting optical fiber cables is also more critical. Glass can not withstand constant high vibrations, and in this type of environment a plastic optical fiber may be used, rather than glass, provided the service required is low speed, and over a short distance.

C: Hardware employed

1) Connector types

Placing connectors onto optical fibers requires a number of skilled techniques, which are beyond the scope of this document, but the basic concept of the process may be discussed. A number of methods of connectorizing fibers have been developed by different manufacturers, but they tend to have many of the same steps in the process, namely preparation, fitting, attachment, curing, scribing and polishing.

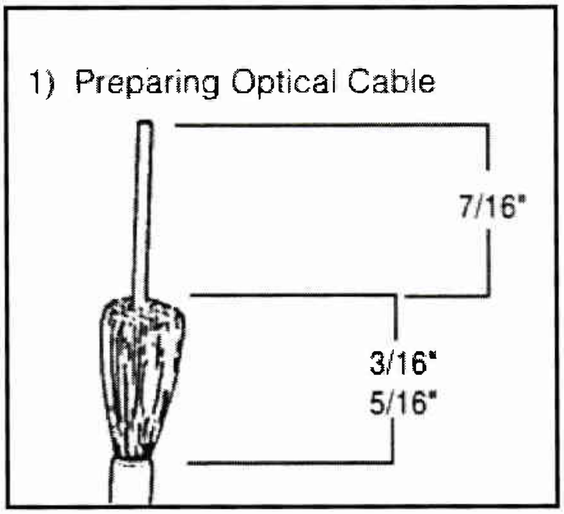


Figure 8-7 Preparation

The optical fiber has to be exposed, and this means removing all the elements of the cable sheath down to the glass cladding/core. Precise lengths of exposed glass and aramid yarn are required at this stage.

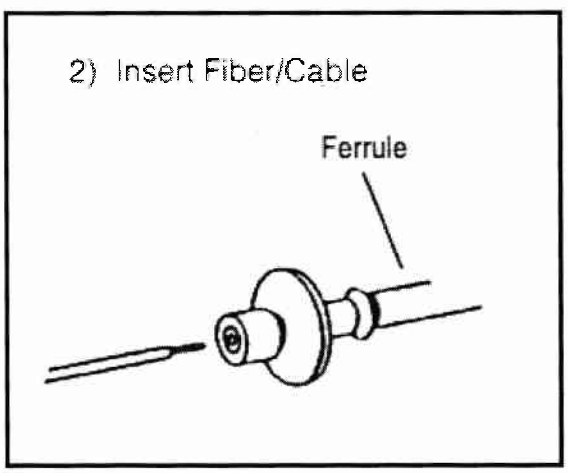


Figure 8-8 Fitting the Optical Fiber

The bare glass fiber is then fitted into the connector end. If the connector uses epoxy glue it may be "dry-fitted" to ensure the ferrule is of the correct size. Crimp fitted connectors may also be dry fitted. Hot melt glue connectors, however, can not be fitted as the ferrule is preloaded with the glue.

One thing to ensure at this time is the length of optical fiber that extends beyond the ferrule end. In a later step this surplus glass will be removed, and it must be of sufficient length to enable an easy cleave with the type of cleaving tool to be used.

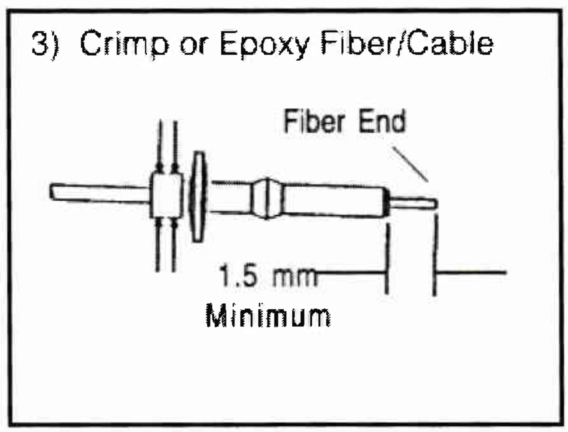


Figure 8-9 Securing the Optical Fiber

Once the fitting is confirmed, the optical fiber is fully seated in the connector, with the aramid yarn placed as required by the particular connector. If an epoxy connector is being used, the epoxy is injected in the connector, and then the optical fiber inserted. If a hot melt connector is used, the connector is heated in the appropriate oven until the glue is soft, and then the optical fiber is inserted in the hot, melted glue. If using a crimp connector is used, the optical fiber is seated as in the dry fit.

4) Cure the Epoxy/Connector
(oven shown)

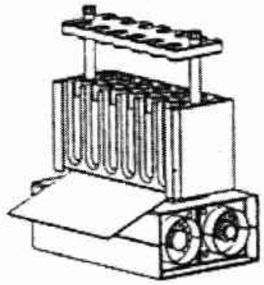


Figure 8-10 Curing the Adhesive

Whenever an adhesive is used, some form of curing is required. Some epoxy glues require curing in a heated oven, while others require a Ultra-violet light source (similar to the kind of adhesives used by a dentist). Hot melt connectors just require a cooling down period.

Whatever type of curing method is used, it is critical to ensure that the process goes undisturbed.

5) Scribing the Fiber

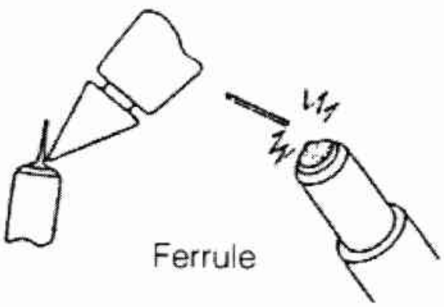


Figure 8-11 Scribing the Optical Fiber

Once the optical fiber is secured in the connector, the surplus glass extending beyond the ferrule must be cleaved. An appropriate cleaving tool is used to "score" a faint scratch across the glass. A longitudinal stress is then applied to the surplus and the glass will cleave, or break just above the ferrule end.

This process is much like cutting a pane of glass for a window pane.

6) Polish in Figure 8 Motion Using
Finer Sheets of Lapping Film

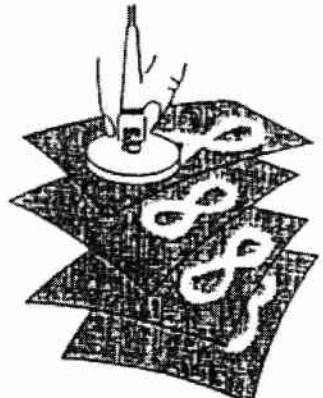


Figure 8-12 Polishing the Fiber

The cleaved end will be rough and will require substantial polishing in order to produce a mirror-like finish to the optical fiber and a facet end that is perpendicular to the ferrule.

In order to produce the best possible facet, the lapping film must be chosen to so that the size of the grit leaves very small scratches across the face, smaller than the wavelengths of light used even. A typical connector may require 2 or 3 lapping films in decreasing grit size. The figure 8 shape used when polishing presents a continuously changing attack on the optical fiber, whereas a steady "back and forth" motion would create deep, parallel scores in the optical fiber face which would cause high losses due to the scattering of the light pulses at the facet.

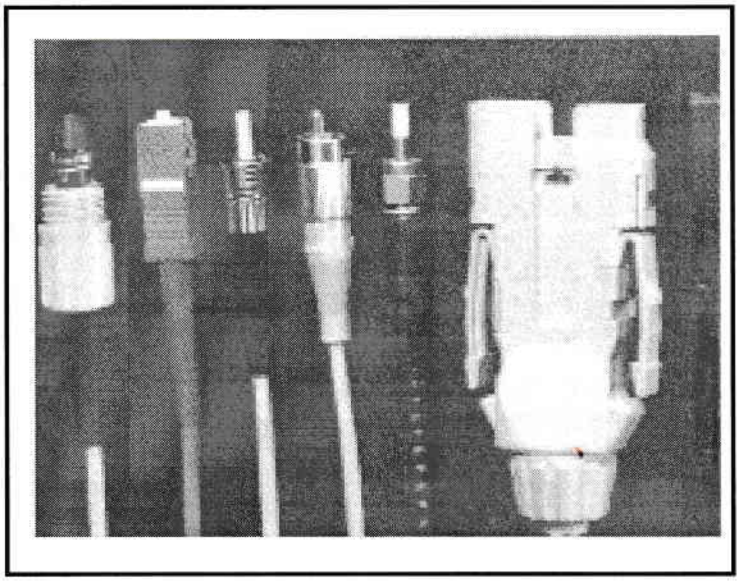


Figure 8-13 Selection of Fiber Optic Connectors

Figure 8-13 shows a number of different fiber optic connector, including Bi-conic (far left), 568SC type (2nd from left), SC-type (3rd from left) and Fiber Distributed Data Interface (far right). Most of these connectors can be constructed using Epoxy, Hot Melt, or crimp construction methods. Many modern connectors come pre-built with a pig-tail, a length of jacketed fiber, which is then spliced to the cable run. In these connectors, the actual optical fiber face is never touched; only a fusion splice is required in order to complete the connector.

2) Mechanical Splice

A mechanical splice is designed to bring the optical fibers close to each other and align them. A typical mechanical splice has index-matching gel in the centre to reduce the losses due to a large differential between the index of refraction of air and the glass. An efficient splice requires a precise cleave at the recommended length for the splice used. If the cladding/core is too short, the ends will be to far apart, and if too long, the cladding/core will not be held properly. An additional issue is the requirement for a perpendicular cleave and a mirror finish. It is not possible to polish the fiber in a splice, because there is no ferrule to support the glass fiber while polishing. For these reasons both mechanical and fusion splicing requires the best cleaving tool you have on hand.

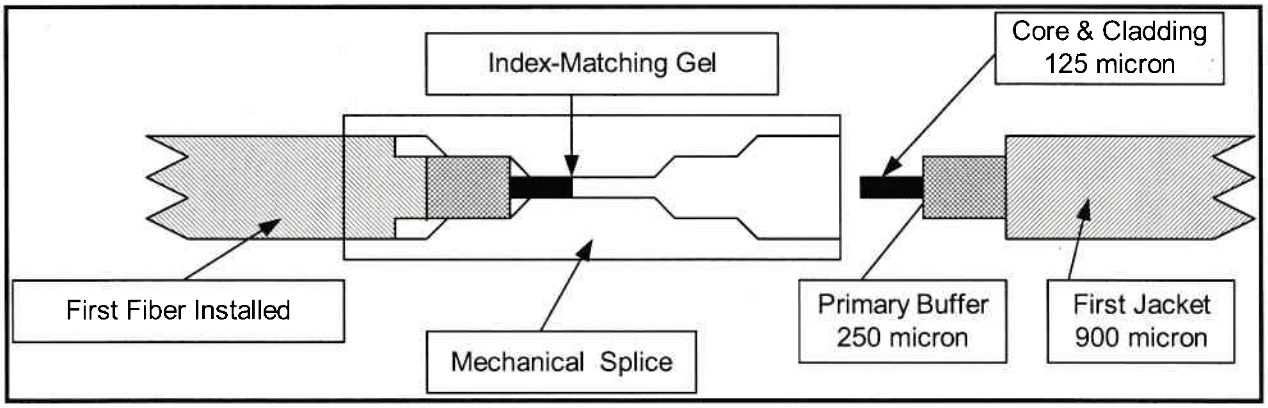


Figure 8-14 Mechanical Splice for Fiber Optic Cables

3) <u>Fusion Splice</u>

Mechanical splices are good as emergency connections, but they tend to have high losses, and are not totally acceptable as a permanent connection. The process of fusion splicing involves heat, as maybe expected from the term. Each of the two fibers to be joined is stripped down to its cladding/core component, and cleaved at a precise length. The cleaving tool used must again be the best you have, because a perpendicular, mirror-finish is required for a successful splice.

The two fiber ends are placed into a pair of fiber sleds in the fusion splicer. The splicer sleds bring the two ends into close proximity, a set of electrode produce a tightly controlled arc which heats up the glass to its melting point. The fibers are pushed together, and "fused" into a single fiber. When the splice is cooled down a splice protector is p-laced over the bare glass, and the fusion splice is complete.

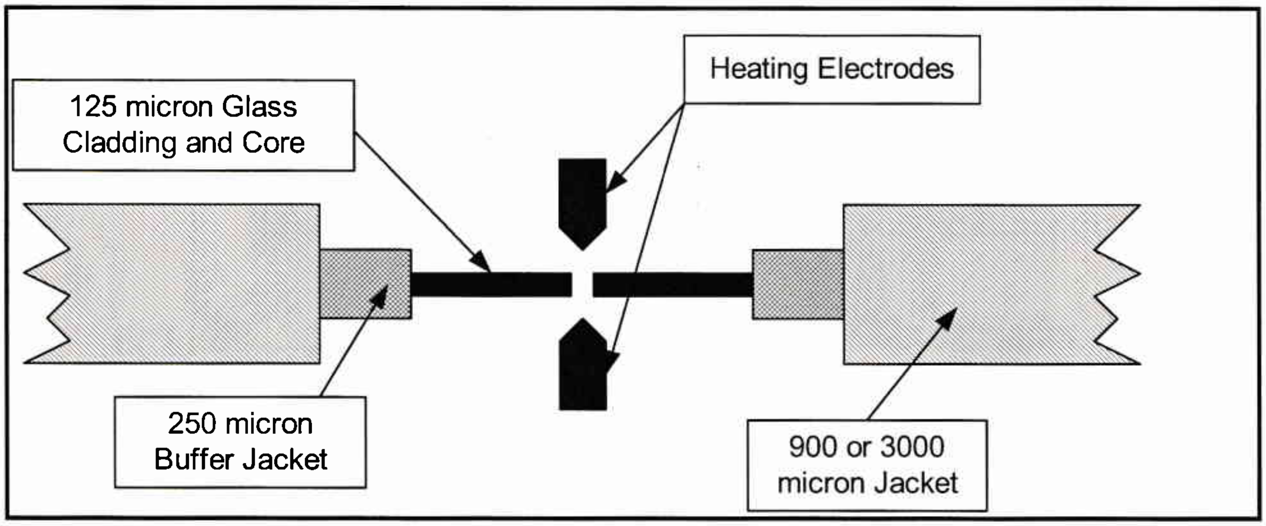


Figure 8-15 Fusion Splicing an Optical Fiber

4) <u>Fiber Optic Patch Panel</u>

Fiber optics patch panels serve the same purpose as their copper counterparts including;

- Providing a termination point for horizontal and backbone cables
- Providing cross-connection points for interconnects
- Providing a method of storing and protecting optic fiber slack

Figure 8-16 below shows the back of a fiber optic patch panel to show the slack try used to hold the loose fiber optic cables.

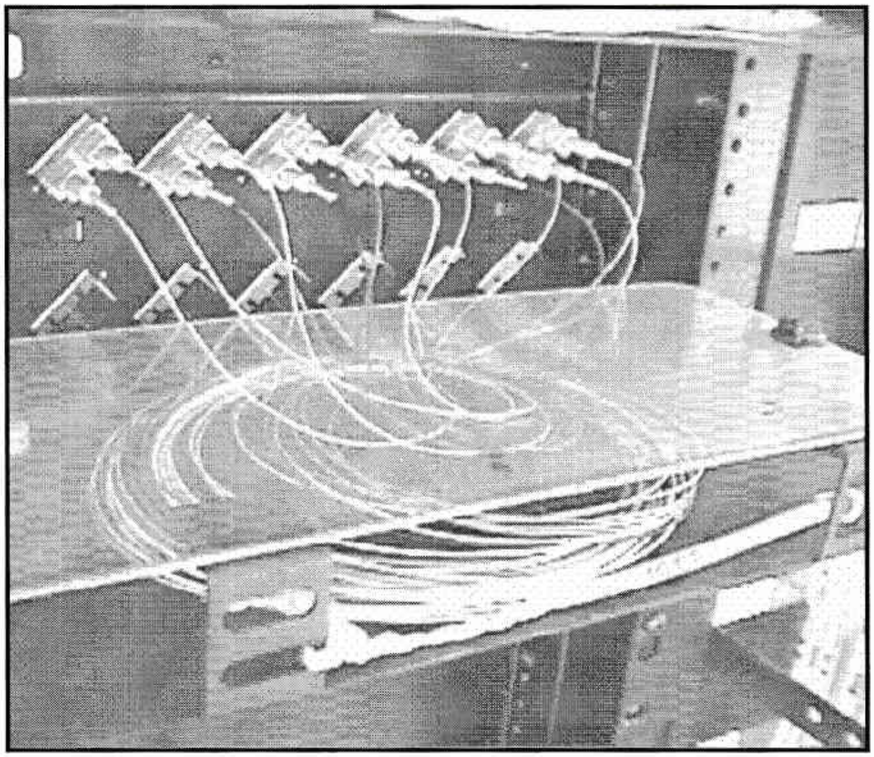


Figure 8-16 Fiber Optic Patch Panel & Slack Tray

Section 8 Summary

Light Theory
- Reflection, Refraction
- Speed of light varies with materials
- Index of Refraction
- Total Internal Reflection at Critical Angle

Optical Fiber
- Core has higher Index, lower speed of light
- Cladding has lower Index, higher speed of light
- Multi-mode fibers have a larger core size than Single-mode fibers

Benefits
- Light weight, small size
- Wide Bandwidth, high speed
- Low Losses, Security and Safety

Drawbacks
- Fragile, special handling required
- Trained technicians required

Section 9: Test Equipment for Networks

A: Toner and Chasers

Model 77A and 77M Tone Test Sets

9-1. GENERAL

This section provides information on the "Tracer" Models 77A & 77M manufactured by Progressive Electronics, Inc.

9.2. DESCRIPTION

The Tracer, Models 77A & 77M (See Figure 10-1), are housed in a yellow high-impact plastic case which measures 1-1/4″ × 2″ ×2-1/4″, weighs 4 ounces and is powered by (1) 9V NEDA Type 1604 battery. Red and black test leads are provided on both models. The 77M, in addition to the 2 leads, has a standard 4 conductor modular cord and plug. A 3 position toggle switch controls the modes of operation plus a (LED) Light Emitting Diode is provided for line polarity testing. A tone selector switch (See Figure 9.2), located inside the test set is provided for choosing either a single solid tone or dual alternating tone. The Tracers and compatible with ESS, Step & Crossbar, and the output tone is isolated from DC voltages.

9.3. OPERATION

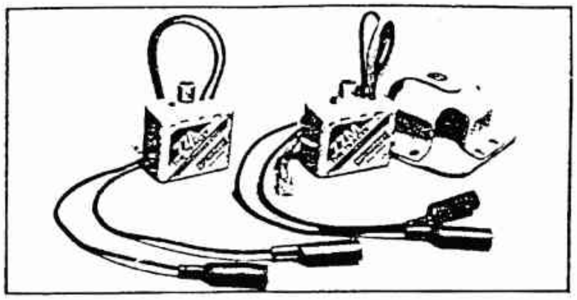


Figure 9-1 Tracers Models 77A & 77M

9.3-1 IDENTIFYING TIP & RING

USE "OFF" POSITION (Central office battery must be present to perform this test)

a) Connect the BLACK lead to the ground.

b) Probe both sides of the line with the RED test lead.

c) The indicator lamp (LED) will light when the RED test lead contacts the RING SIDE of the line.

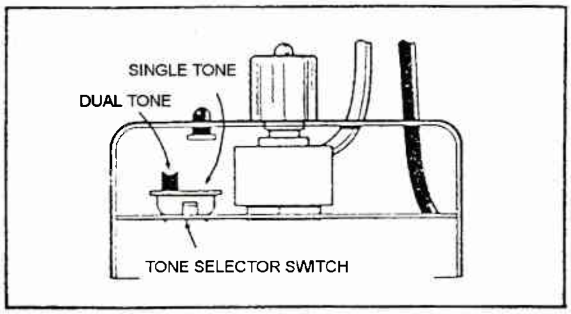


Figure 9-2 Tone Selector Switch

NOTE IF A GROUND IS NOT AVAILABLE FOR REFERENCE, CONNECT THE TEST LEADS ACROSS THE PAIR. THE INDICATOR LAMP WILL LIGHT WHEN THE RED TEST LEAD IS CONNECTED TO THE RING SIDE OF THE LINE AND THE BLACK LEAD TO THE TIP.

9.3-2 INDICATING LINE CONDITION
USE "OFF" POSITION

a) Connect the RED test lead to the RING SIDE of the line and the BLACK to the TIP.
b) Watch the indicator lamp:
   1. A BRIGHT lamp indicates a CLEAR line.
   2. A DIM lamp indicates a BUSY line.
   3. A BRIGHTLY FLASHING lamp indicates a RINGING line.

NOTE: CONNECTING IN REVERSE POLARITY, A DIMLY FLASHING LAMP WILL RESULT WITH THE RINGING LINE TEST. IF THE TEST IS CONNECTED PRIOR TO RINGING, THE CALL WILL BE INTERCEPTED.

9.3-3 VERIFYING LINES

USE "OFF" THEN "CONT" POSITIONS

a) Dial the line to be verified.
b) While the line is ringing, connect the RED lead to the RING side of the line and the BLACK lead to the TIP.
c) In the "OFF" position, the indicator lamp will flash when the test leads are connected across the subject pair.
d) To verify identification, monitor the line and switch the test set to "CONT." This will terminate the call on the subject line.

9.3-4 SUPPLYING TALK POWER

USE "CONT" POSITION

a) Connect the test leads across a handset, or headset, and the line (See Figure 9.3).
b) With the test set in the "CONT" position, a "dead line" is supplied with talk power.

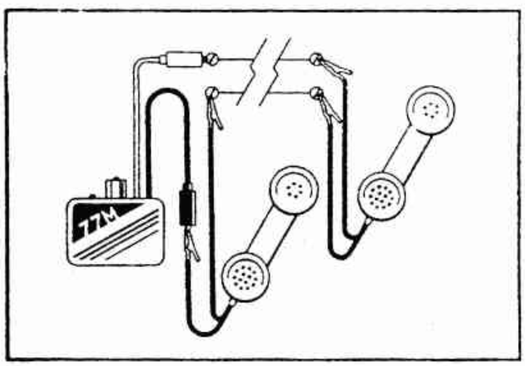


Figure 9-3 Supplying Talk Power

9.3-5 SENDING TONE

USE "TONE" POSITION

a) Connect the test leads across the line, or attach one lead to ground and one lead to either side of the line (See Figure 9.4).
b) A dual alternating tone, or a single solid tone, can be selected from the switch inside the unit.
c) Probe the suspected wires with the PE1 Model 200B Line-Aid, Inductive Amplifier. Reception of tone will be strongest on the subject wire. In cases of ready access to bare conductors, a handset or headset may be used to receive the tone.

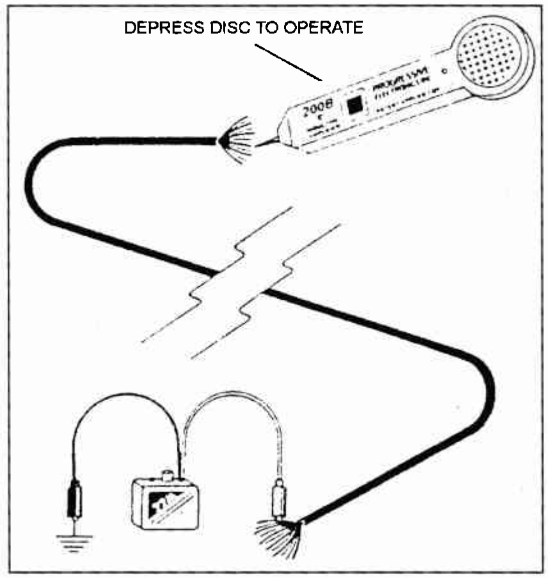


Figure 9-4 Sending Tone

9.3.6 TESTING CONTINUITY USING TONES

USE "TONE" POSITION

a) Connect the test leads to a subject pair.
b) Using a handset or headset at the remote end, touch the wire end(s) with the clip lead(s).
c) Reception of tone is an indication of continuity.

9.3.7 MODULAR TESTING

77M ONLY

a) All above tests are available through the modular plug for Line 1 only — red and green wires.

9.4 MAINTENANCE

9.4.1 77A or 77M BATTERY REPLACEMENT INSTRUCTIONS

1. Remove screw from rear of set holding front cover.
2. Remove front cover.
3. Remove and replace battery.
4. Replace front cover and screw. Take care when replacing screw not to over tighten.

B: Linesman Test Set

HARRIS CORPORATION DRACON DIVISION

P/N 0II-722333-001
Issue 4, January 1995

TS21 CRAFT TEST SET
DESCRIPTION AND USE

CONTENTS	PAGE
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2. DESCRIPTION	1
3. CONTROLS AND INDICATORS	2
4. CONNECTIONS	3
5. OPERATION	3
6. MAINTENANCE	4

WARNING

Good safety practices prohibit the connection of the TS21 and similar test sets to 117 volts AC commercial electrical power; and should the TS21 be connected to commercial power, all warranties are immediately voided.

1. GENERAL

1.01 The Dracon TS21 Craft Test Set employs the latest technology in integrated circuit design to provide both DTMF (Touch Tone) and dial pulse output. The TS21 also provides last number redial, and field replaceable line cords and belt clips. This Test Set, often called a "butt-in," is a self-contained, line-powered, portable handset used by installers, repair technicians, and other authorized personnel for line testing and temporary communications.

2. DESCRIPTION

2.01 Physical Characteristics (Figure 1):

(a) The housing (A) is injection molded of high impact polycarbonate which provides excellent insulating properties. The case is designed to give rugged service and withstand the rough handling and shocks normally associated with craft tools.

(b) The back of the hand grip (B) is contoured and has a non-slip surface, freeing both hands while the Test Set rests on the shoulder.

(c) The keypad (C) has 12 buttons on a black plastic bezel that is recessed into the receiver end of the housing. The recessed bezel provides physical protection to the keypad and prevents accidental button operation.

(d) The spring-loaded belt clip (D), located on the transmitter end of the housing, ensures a secure connection to a belt loop or D-ring. The belt clip may be replaced in the field (see section 6.01).

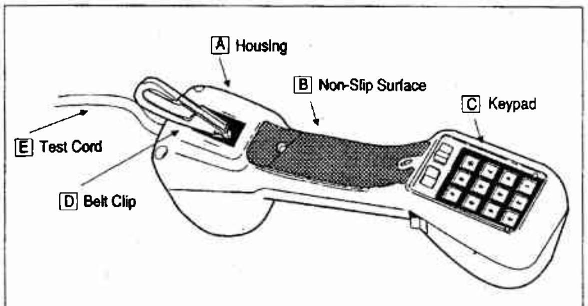


Figure 1 – Physical Characteristics

(e) The test sets are equipped with several different cord configurations (E). The line cords may be replaced in the field (see sections 4 and 6.02).

2.02 Specifications:

(a) Electrical

Loop Limit	2 kΩ maximum at 48 VDC (nominal 20 mA minimum loop current)
DC Resistance (Talk Mode)	<300 Ω (similar to WECO 10131A and BECO 801)
Monitor Impedance	6 kΩ minimum at 1 kHz
Rotary Dial Output	
Pulsing Rate	10 pps + 0.5 pps
Percent Break	61% ± 2%
Interdigit Interval	1000 ms typical
Leakage During Break	>50 kΩ
DTMF Output	
Tone Frequency Error	± 1% maximum
Level per Tone Pair	+1 dBm maximum –9 dBm minimum
High versus Low Tone Difference	4 dB maximum

(b) Physical

Length	9-11/16 inches (24.6 cm)
Width	2-11/16 inches (6.83 cm)
Height	3-11/16 inches (9.37 cm)
Weight	21 ounces (.600 kg) typical

(c) Environmental

Temperature	Operating: –34 to 60 °C Storage: –40 to 66 °C
Altitude	To 10,000 feet
Relative Humidity	5 to 95%

Specifications subject to change without notice.

2.03 Standard TS21 Models:

*Model No.	**Cord Type	Ground Start Switch
21800-081	STD	NO
21800-082	SBN	NO
21800-084	SP	NO
21800-087	3W	YES
21800-088	SPR	NO
21800-089	ABN	NO

**Special production models are indicated by a number in place of the zero following the "-", -180, -281, -384, etc. These models are identical to their corresponding standard model, except for color and logo.*

***See cord descriptions, Section 4.*

3. CONTROLS AND INDICATORS

3.01 Voice and polarity controls (Figure 2):

(a) **Talk/Monitor (T/M) Switch.** This rocker switch is located on the side of the test set. The T (TALK) position establishes an off-hook condition for dialing and talking as a common battery telephone. The M (MONITOR) position removes the transmitter from the circuit, and provides a high impedance coupling to the line. The M position allows line monitoring without disrupting conversations, data, or signaling.

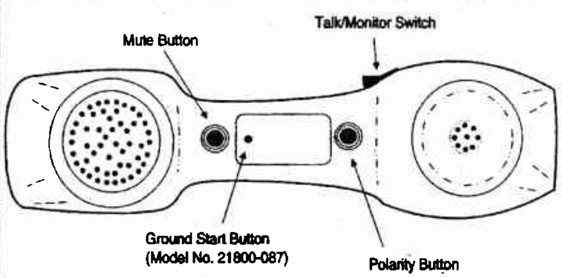


Figure 2 – Voice and Polarity Controls

(b) **Mute (M) Button.** This non-locking push button, labeled M, is located on the inside of the hand grip just above the transmitter. When pressed, this button mutes the transmitter, eliminating sidetone, and providing improved intelligibility through the receiver in noisy locations.

(c) **Polarity Button.** This non-locking push button, labeled P, is located on the inside of the hand grip just below the receiver. When pressed, the button will activate one of the polarity LEDs, located at the top of the keypad, showing the current polarity of a telephone line or a low voltage battery source. See section 3.02(d).

(d) **Ground Start Button (optional).** Located between the MUTE button and the Polarity switch. When pressed, this small black button connects the ground (green) lead to the ring (red) lead of the special three-conductor ground start cord, initiating a ground start line seizure.

3.02 Keypad Controls and Indicators (Figure 3):

(a) **Keys.** The 12 standard keys will send either DTMF tones or dial pulses, depending on the MODE switch setting. See (b).

(b) **MODE Switch.** This two-position locking rocker switch, labeled MODE, is located on the lower-right keypad bezel. The switch selects the signaling output: TONE for DTMF or PULSE for dial pulse.

(c) **Keypad Switch.** This two-position locking rocker switch, labeled KEYPAD, is located on the lower left keypad bezel. With the switch in the IN position, the Test Set operates as a telephone; this mode is used for all normal communications. The OUT position bypasses the Test Set circuitry, including the keypad. In this mode, signaling is not possible, but the TS21 will operate at very low voltages, much like standard Test Sets currently in use. The OUT position is recommended when testing at or near the loop limit (2,000 ohms at 48 volts DC), or when testing on dry circuits. The OUT position must be used when the circuit voltage is six volts or less, such as when using tones or other test devices as a source of talk battery.

(d) **Polarity LEDs.** These round LEDs, one green and one red, are located at the top of the keypad. One LED will illuminate when the polarity button is pressed, to indicate line polarity. See section 5.02. The green LED will light if the red test lead is connected to the ring (negative) side of the line and the black test lead is connected to the tip (positive) side of the line. The red LED will light if the test leads are reversed; that is, with the red test lead connected to the tip (positive) side and with the black test lead connected to the ring (negative) side.

CAUTION: Operation of the P button on a busy circuit may cause annoying clicks or service interruptions.

(e) **Last Number Dialed (#) Button.** The # (pound) key serves as a last number dialed button when the

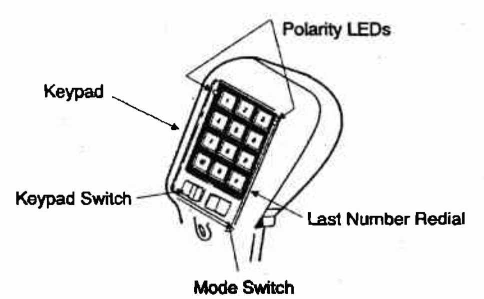


Figure 3 – Keypad

MODE switch is in the PULSE position. Pressing the # key will redial the last number dialed.

Note: The redial memory has a two minute time limit after the TS21 has been disconnected from a working telephone line. After two minutes, the number will be lost from memory.

4. CONNECTIONS

4.01 Cords (Figure 4):

(a) **Standard Cord with Piercing Pin (STD).** This cord consists of one red and one black conductor, each approximately five feet long. Each conductor is fitted with an alligator clip offset 20° to minimize clip shorting. The clips have insulation piercing spikes and a neoprene boot. Cord Number: P3218-028.

(b) **Angled Bed-of-Nails Cord (ABN).** The angled Bed-of-Nails cord is similar to the STD cord, except that each alligator clip is equipped with a "bed-of-nails" in addition to the insulation piercing spike. Cord Number: P3218-234.

(c) **Central Office Plug Cord (SP).** This cord is fitted with a type 346A female plug and is approximately one foot long. The plug allows the use of a variety of different test cords equipped with the matching 471A male connector. Cord Number: P3218-232.

(d) **Central Office Plug and Resistor Cord (SPR).** This cord is fitted with a type 346A female plug and switchable 1500 ohms resistor, and is approx- imately 18 inches long. When switched on, the resistor is inserted in series with the ring side of the cord to simulate a long loop condition. The plug allows the use of a variety of different test cords equipped with the matching 471A male connector. Cord Number: P3218-233.

(e) **Bed-of-Nails Cord (SBN).** This cord is identical to the standard (STD) cord, except that each alligator clip is equipped with a bed-of-nails in addition to an insulation piercing spike, and the clips are not offset as are the STD clips. Cord Number: P3218-024.

(f) **Ground Start Cord (3W).** This cord consists of one red, one black, and one green fabric covered tinsel conductor approximately five feet long, each fitted with an alligator clip of the type used on the standard cord. Pressing the GROUND START button connects the green (ground) conductor to the red (ring) conductor inside the Test Set. Cord Number: P3218-025.

5. OPERATION

5.01 **Monitoring.** Move the T/M switch to M (KEYPAD IN/OUT and MODE switches may be in either position), and connect the line leads to the telephone line under test. Monitoring may now be done without disrupting traffic.

Note: The TS21 is not polarity sensitive and will function normally regardless of telephone line polarity.

5.02 **Polarity Check.** Move the T/M switch to M. Connect the line leads to the telephone line under test. Verify that the telephone line is idle. Press and hold the depressed P button. The green LED will light if the red test lead is connected to the ring (negative) side of the line and the black test lead is connected to the tip (positive) side of the line. The red LED will light if the test leads are reversed; that is, with the red test lead connected to the tip (positive) side and with the black test lead connected to the ring (negative) side.

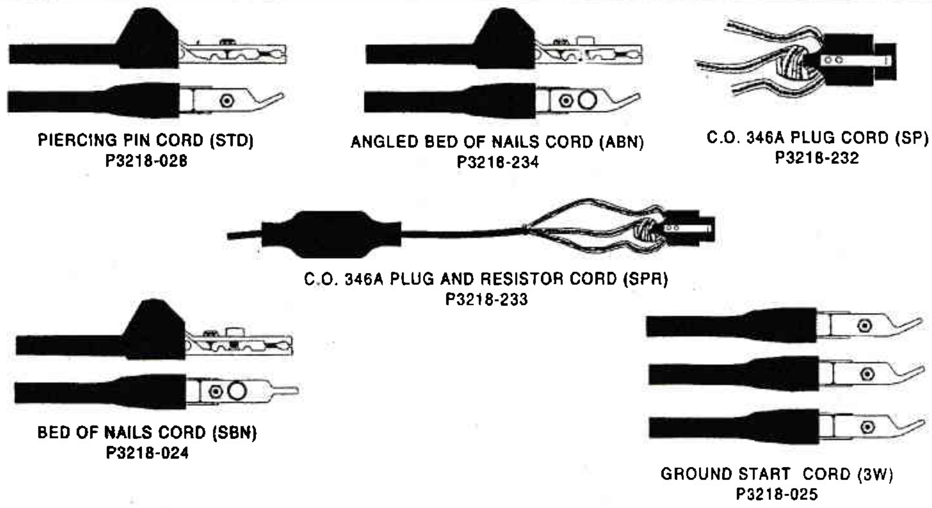


Figure 4 – Cords

CAUTION: Operation of the POLARITY button on a busy circuit may cause annoying clicks or service interruptions. Operation of the switch on an idle telephone line may cause telephone line seizure.

5.03 Dialing.

(a) Move the KEYPAD switch to the IN position. Move the MODE switch to either TONE or PULSE, depending on the type of dial signaling required. Move the T/M switch to the M position. Connect the line cord clips to the telephone line. Listen to verify that the telephone line is idle.

(b) Move the T/M switch to T position and verify that dial tone is received (when furnished). Enter the desired number to be called on the keypad. If tone signaling has been selected, the tones associated with each digit will be generated as each respective button is pressed. If rotary dial pulse signaling has been selected, the desired number may be entered at any rate on the keypad; digits will automatically be pulsed out at the correct rate. To end the call, return the T/M switch to the M position.

5.04 Last Number Redial. Move the MODE switch to the PULSE position. The last number dialed can be automatically redialed by using the following procedure (the number cannot exceed 18 digits):

(a) Go on-hook (move the T/M switch to the M position) for at least 1/2 second.

(b) Move T/M switch back to T position.

(c) Press the # (pound) key and the number will be automatically redialed.

In the off-hook mode, if any key other than the # button is pressed, the previously stored number will be erased.

Note: The redial memory has a two minute time limit after the Test Set has been disconnected from a working telephone line. After two minutes, the number will be lost from memory.

5.05 Ground Start Line Seizure (optional). Pressing the GROUND START button connects together the ground (green) and ring (red) leads of the three-conductor test cord.

5.06 Operation On Low Voltage or Dry Circuits.

(a) Move the keypad switch to OUT. This position bypasses the circuitry of the Test Set and increases the loop limit. The keypad will not operate in this mode, but all other functions operate normally.

(b) Move the T/M switch to M. Connect line leads to the circuit under test. Verify that the circuit is idle. Move the T/M switch to T for two-way communications.

(c) When operating on low voltage or dry circuits, a minimum of three volts DC talking battery is required.

5.07 Troubleshooting. The following troubleshooting procedures are based largely on the audible *click* heard in the receiver of the TS21 when the two Test Set leads are placed on battery potential and ground respectively, or across the terminal of an electrically charged capacitor. These *clicks* and other sounds can greatly help a skilled crafts person in locating open circuits, shorts, crosses, and grounds.

(a) To locate a short circuit, open one side of the telephone line and place the test set in the loop – one lead to each side of the opened line. On the CO side of the fault, a loud *click* will be heard; on the field side of the fault, **no** *click* will be heard.

(b) Locating an open circuit is done by bridging the test set across the circuit line – one test lead on tip, the other on ring. Moving away from the CO, the fault is at the point where the loud *click* disappears.

(c) Continuity of each side of the loop may be verified by placing one of the line leads on a local ground and the other on the conductor in question. On a good ring conductor, a *click* will be heard; on a good tip conductor, an inductive *hum* will be heard (due to the difference in ground potential between the CO ground and the local ground).

Note: For a full discussion on these troubleshooting procedures, refer to your company's practices, or to *ABC of The Telephone, Volume* 2, Chapters 13, 14, and 15.

CAUTION: When testing circuits that are relatively close to the battery source, the *clicks* may be loud enough to cause temporary acoustical shock if the receiver is held too tightly against the ear. The TS21 is designed to rest comfortably on the shoulder with the receiver away from the ear. It should be used in this position when listening for *clicks*.

C: Category Testing: Cable Scanners

1) Concepts Behind Reflectometers

Testing a copper pair to 100 MHz and above requires a highly sophisticated piece of equipment. Standards such as the TIA/EIA 568B required accurate measurements of numerous line impairments, across a wide range of frequencies. Near End Cross Talk (NEXT) for example requires tests at 800 frequencies from very low frequencies, up to 100 MHz. Furthermore, the tests require intelligent equipment at both ends of the cable.

The limit of a specific parameter may depend on the frequency of the test, the length of the cable, and the category of the cable being tested. Although "frequency runs" as they are called, have been around as long as telephones have been, the number of tests and the range of frequencies to be tested require some form of automation, which is provided by the latest generation of cable scanners.

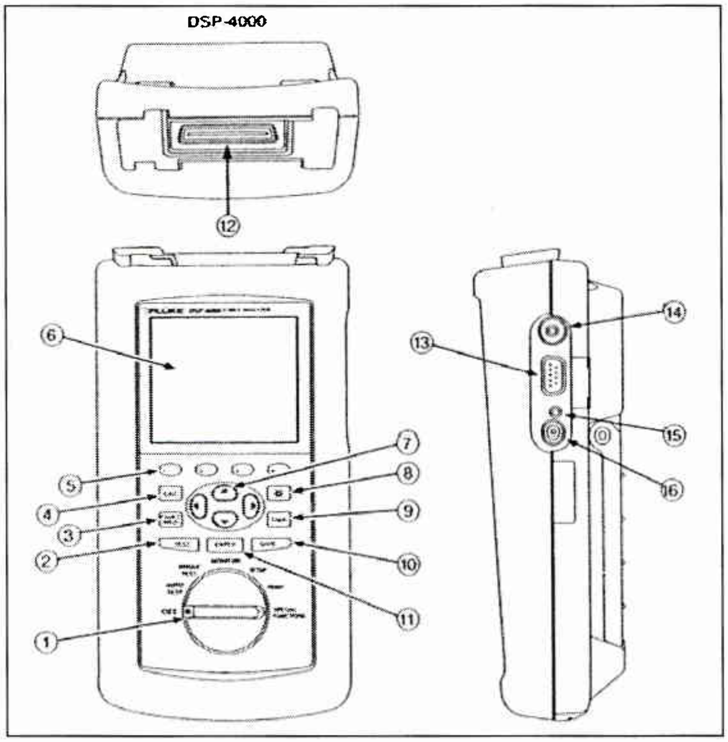


Figure 9-5 Fluke DPS4000 Main Unit Controls

Reflectometers work on the principle of voltage reflections on an open or a shorted metallic pair of conductors. Referring to Figure xx below, let us assume that the output impedance of the cable scanner is equal to the input impedance of the cable, which for Category cables is 100 Ohms. For the purposes here, Impedance can be considered to be a form of AC resistance.

If we launch a 3 volt pulse from our cable scanner, one half of the voltage (1.5 V) will be impressed across the scanner, and one half of the voltage (1.5 V) will travel down the conductor pair. As this voltage travels towards the open ended conductor, the conductor takes on a 1.5 V charge. When the voltage surge reaches the open end, the current carrying the voltage can not travel any further. Like an ocean wave hitting a breakwater, the current reverses direction,

carrying the same 1.5 V surge, now added to the existing 1.5 V already on the line. As a result, the conductor takes on a 3 volt differential with respect to the other conductor.

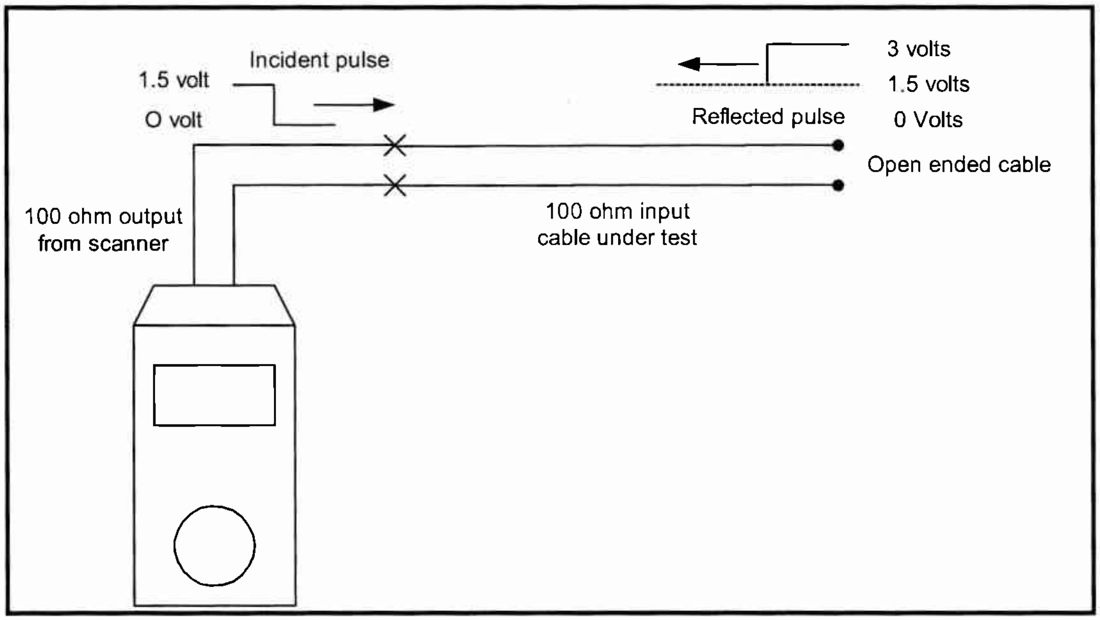


Figure 9-6 Voltage Surge Reflection from Open Pair

If the line has a short at the end, the voltage pulse "turns the corner" and then charges up the return conductor (lower conductor in Figure 9.6).

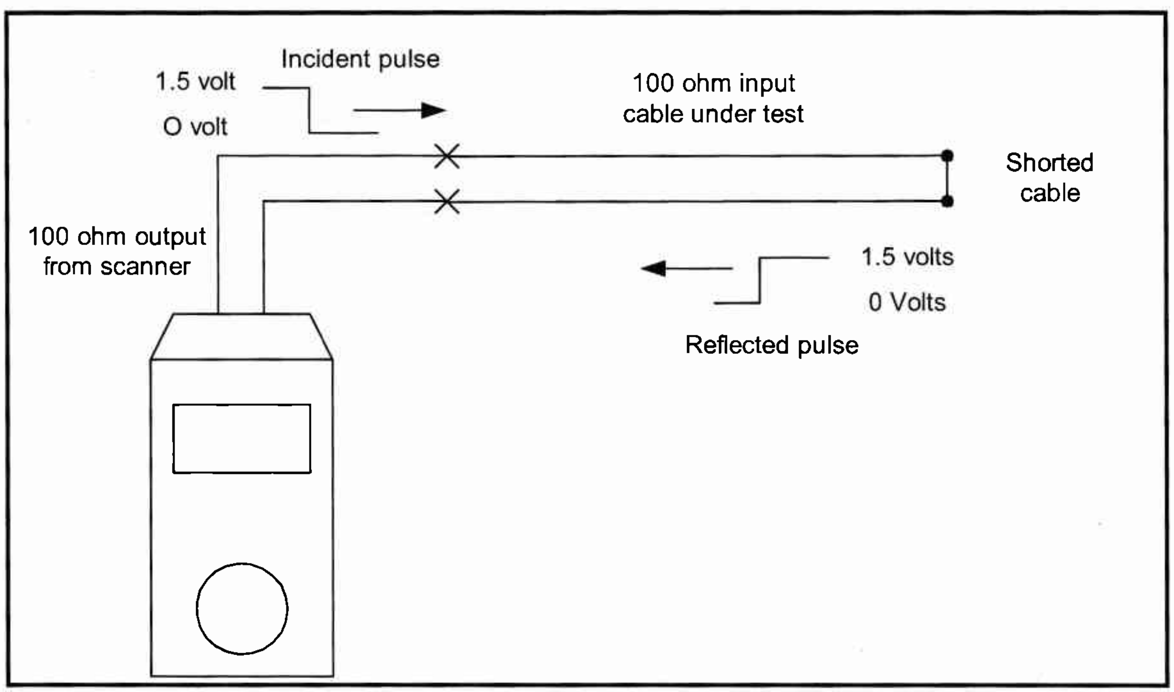


Figure 9-7 Voltage Surge Reflection from Shorted Pair

When the conductors are terminated in a 100 ohm device, such as a NIC card or the port of a Hub or Layer 2 Switch, the voltage sent down the conductor is absorbed by the terminating device, and no voltage is reflected, which is what we want in a properly operating network.

For test purposes the cable scanner measures the time between the pulse launch and the reflection, and the polarity of the reflection. Once the meter is given the velocity of propagation of an electrical signal on the conductors, it can then determine the length of the cable, and the condition of the far end (Open, Shorted, Terminated, or values between an open and a short.)

2) Characteristic Impedance

The velocity of propagation of the signal depends on the conductor size, the physical relationship of the conductors and the material between the conductors. At high frequencies the cable pair becomes something more than just a resistive copper path. Two conductors running in parallel form a small capacitive circuit. Likewise, the conductors form a small inductive circuit between the pairs. The distributed capacitive and inductive values for a meter of conductor length will remain constant as long as the conductors stay the same distance apart and the material between the conductors does not change. This value is called the Characteristic Impedance of the line, and is 100 ohms in the case of UTP cables. The coaxial cable used by the cable TV has a characteristic impedance of 75 ohms.

3) Nominal Velocity of Propagation

The distributed capacitance and inductance on the pair cause the electrical signal to propagate a velocity slower than that of the speed of light which is 300 x 10^6 meters per second. In the case of 100 ohm UTP cables, the nominal velocity is approximately 70% that of light, or about 210 x 10^6 meters per second. The NVP value is critical in determining electrical lengths, and may be set using the manufacturers NVP value.

D: Protocol Analyzer

Cable scanners are sufficient to test the physical layer of a LAN, but they do not provide a lot upper level functionality. The DSP4000, for example, will only provide a basic monitor "window" into the LAN protocols, showing traffic and collisions only.

In order to troubleshoot problems in the OSI layers above the Physical Layer, some type of protocol analyzer is required. These devices can analyze the electrical impulses that constitute the digital information, decoding them from their binary codes, and showing the traffic in plain English. LAN protocols such as the IEEE 802.3 (Ethernet) and Token Ring, Layer 3 and 4 Protocols such as Internet Protocol (IP) and Transmission Control Protocol (TCP) can be recognized Most protocol analyzers can even filter traffic, so that the physical devices on the network may be located, their addresses and even upper layer capabilities determined.

All this power required by these devices comes with a cost. These devices are neither inexpensive nor common place. A number of companies make protocol analyzers, either as stand-alone devices or as third-party software.

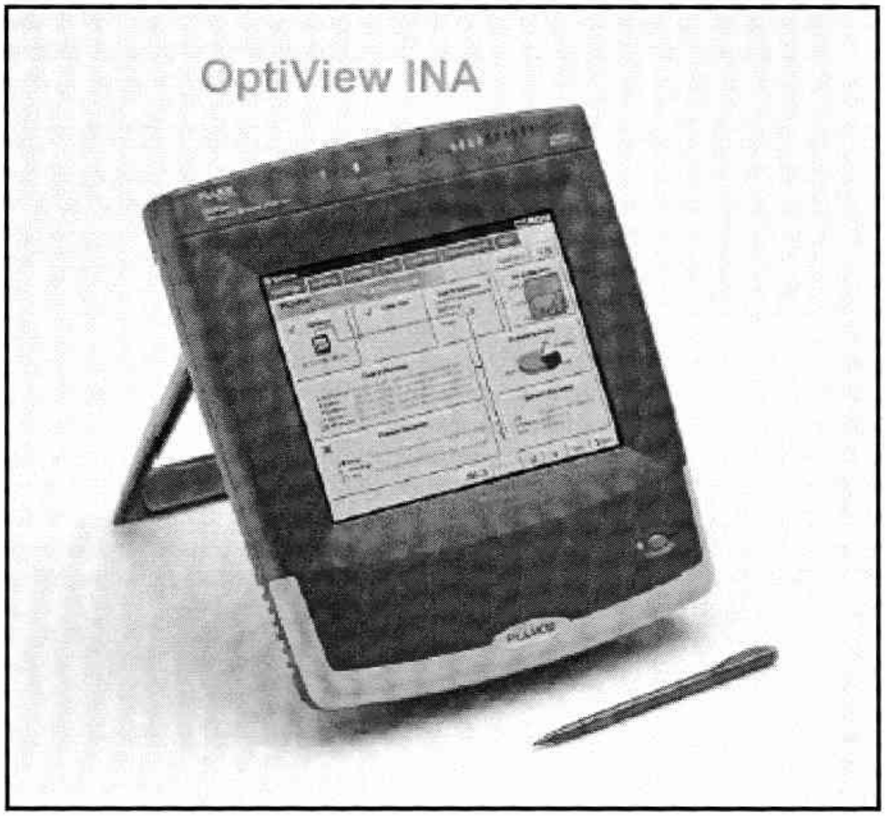


Figure 9-8 Fluke Optiview Protocol Analyzer

Protocol analyzers require a physical connection to the LAN, so that they may trap and analyze all the traffic on the LAN. Depending on how the analyzer is set up, it can record and print Layer 2 and Layer 3 addresses, as well as providing a window into the higher layer protocols.

Figure 9-9 below shows the LAN information presented in a graphic form, showing things like traffic analysis, percentages of traffic by protocol, collisions etc.

Figure 9-10 is a screen snapshot of messages which the analyzer captured. The test set was set to record the Domain Name, the NetBIOS name, the IP address and the MAC address of the frames on the LAN. Looking at the left hand column of the screen snapshot, other possible views include Simple Network Management Protocol (SNMP) traffic, device interrogation, Server and Router mapping, and other network devices.

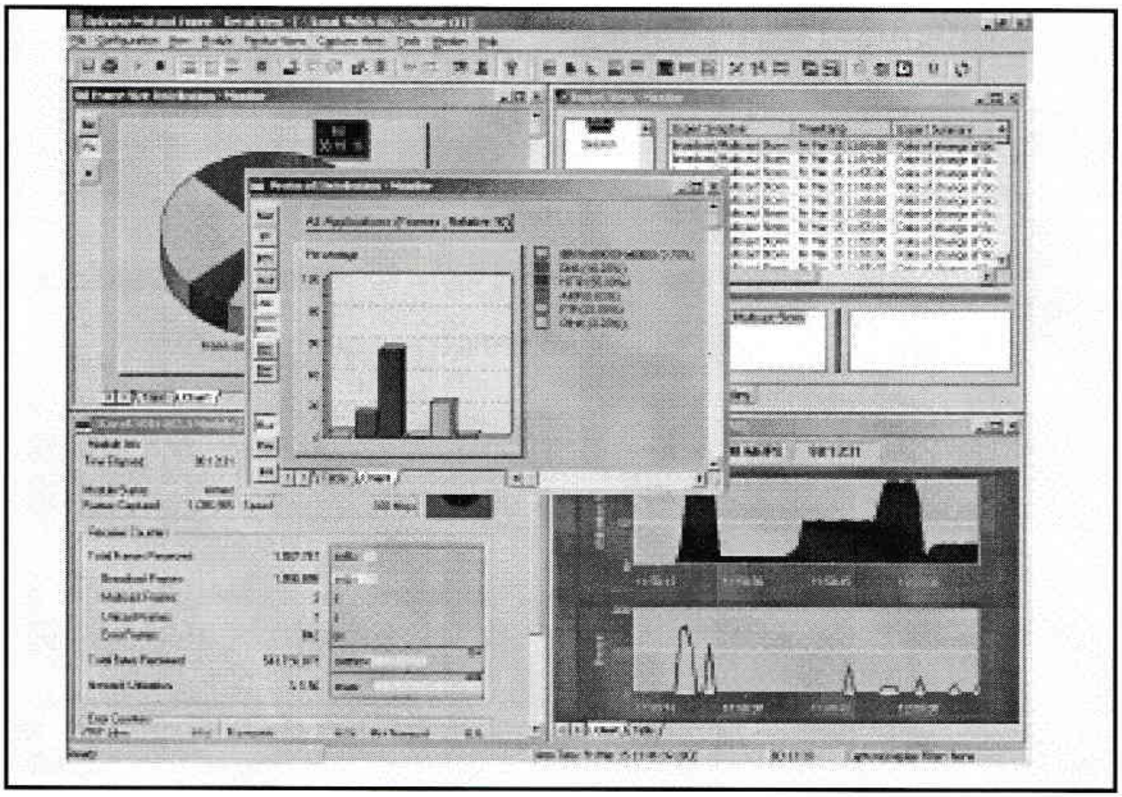


Figure 9-9 Graphic Presentation of LAN Traffic

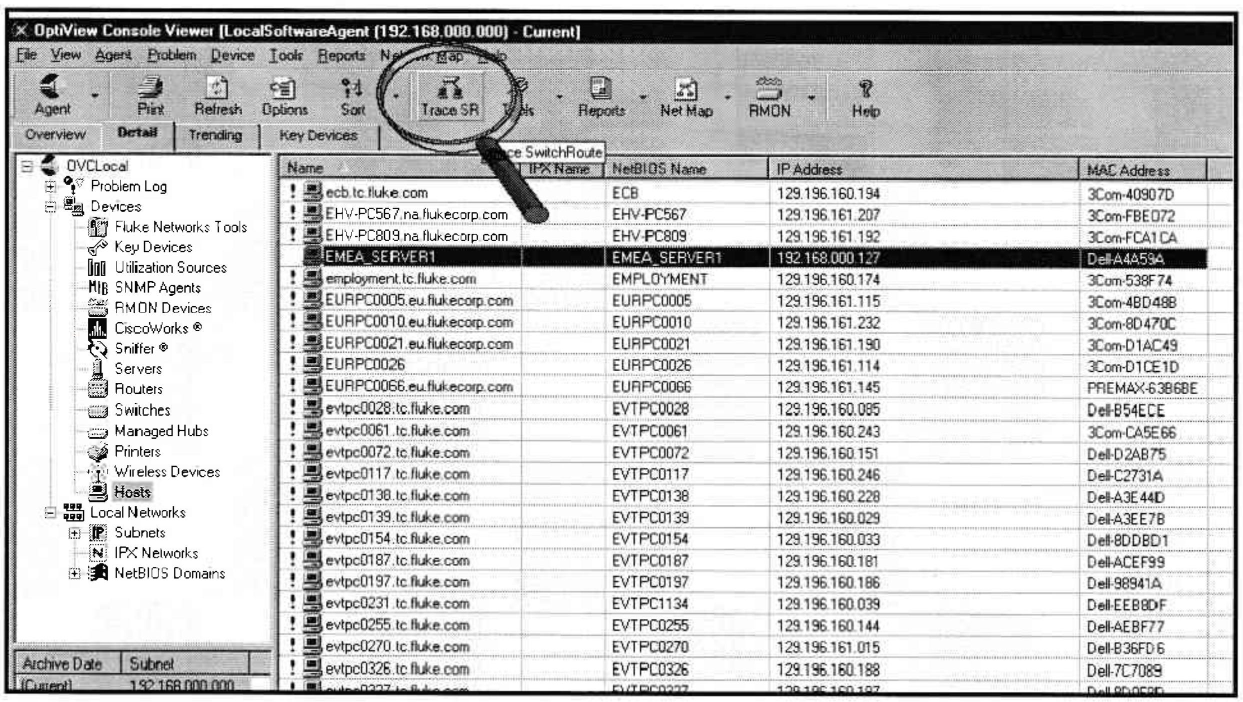


Figure 9-10 Presentation of LAN Layer 2 and Layer 3 Information in Table Form

E: Structured Cable Tests

1) Wire Map

a) Measurement Definition

Wire map is used to identify installation wiring errors. For each of the 8 conductors in the link, wire map should indicate:

Proper pin termination at each end
Continuity to the remote end
Shorts between any two or more conductors
Crossed pairs
Split pairs
Reversed pairs
Shorted pairs
Any other incorrect wiring

A reversed pair occurs when the polarity of one wire pair is reversed at one end of the link (also called a tip/ring reversal). A crossed (or transposed) pair occurs when the two conductors in a wire pair are connected to the position for a different pair at the remote connector. Split pairs occur when pin to pin continuity is maintained but physical pairs are separated. Refer to the figure below for an illustration of correct pairing, a reversed pair, crossed pairs, and split pairs.

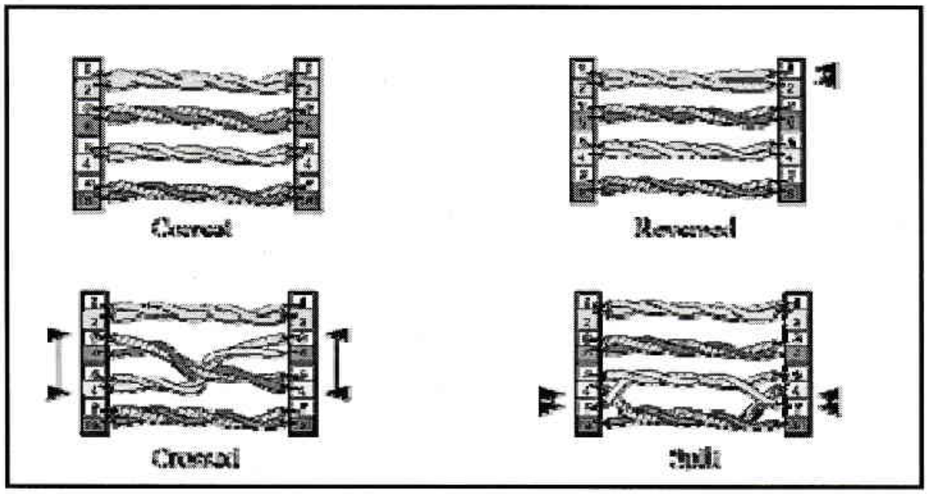


Figure 9-9 Common Wiring Errors

b) Results Interpretation

In most cases you will expect to see straight through connections. With simple tools, such as LED display testers, a lamp will light up indicating a short or open. Advanced tests, such as reversed or split pairs, are often not available in such equipment. While such tools are usually adequate, it must be noted that a passing result does not necessarily guarantee wiring has been installed correctly. In particular, split pair detection requires the measurement of NEXT, which is beyond the capability of low-end testers. Split pairs will cause a high degree of NEXT (typically over 22 dB), which will severely limit available bandwidth on the installed cabling.

In the case of Screened twisted pair cabling you will need to also verify screen continuity. This is usually only available on more advanced certification tools.

Wire map is a fundamental test, but it is important to note that correct wiring does not verify bandwidth performance. Frequency-dependent tests such as NEXT, attenuation, and return loss are critical to ensuring cabling is capable of supporting high-speed applications.

2) DC Loop Resistance

a) Measurement Definition

DC Loop Resistance is the total resistance through two conductors looped at one end of the link. This is usually a function of the conductor diameter and varies only with distance. This measurement is sometimes done to ensure there are no gross misconnections, which can add significant resistance to the link. Note that the wire map test automatically isolates breaks, but not high resistance connections.

DC resistance is often confused with impedance, a term describing the dynamic resistance to signal flow, usually at a specified frequency. Both are measured in ohms because they define different types of opposition to electrical current flow. DC resistance increases proportionately with the length of the cable tested while impedance remains "fairly" constant regardless of length.

From a signalling perspective, attenuation (sometimes called insertion loss) is now a more useful measurement, and DC resistance has become less important.

b) Results Interpretation

Variations in loop resistance between pairs can often be a quick indication of a cabling problem. In a shorted loop-back test environment, the expected value is simply twice the sum of the value expected for the given length.

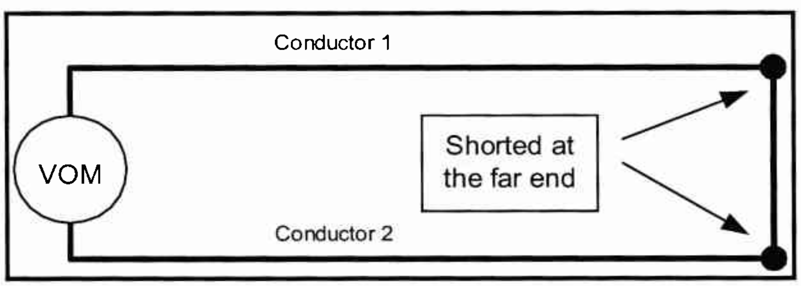


Figure 9-10 DC Resistance Measurements

3) Propagation Delay

a) Measurement Definition

Propagation delay, or delay, is a measure of the time required for a signal to propagate from one end of the circuit to the other. Delay is measured in nanoseconds (nano-Sec). Typical delay for category 5e UTP is a bit less than 5 nano-Sec / meter (worst case allowed is 5.7 nano-S/m). A 100 meter cable might have delay as shown below.

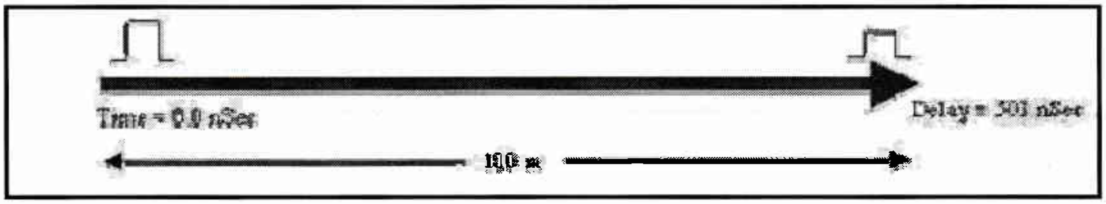


Figure 9-11 Propagation Delay Measurements

Delay is the principle reason for a length limitation in LAN cabling. In many networking applications, such as those employing CSMA/CD, there is a maximum delay that can be supported without losing control of communications.

Nominal Velocity of Propagation (NVP) on the other hand, is different. NVP refers to the inherent speed of signal travel relative to the speed of light in a vacuum (designated as a lower case c). NVP is expressed as a percentage of c, for example, 72%, or 0.72c. All structured wiring cables will have NVP values in the range of 0.6c to 0.9c.

b) Results Interpretation

Delay measurements are relatively straightforward. Most structured wiring standards expect a maximum horizontal delay of 570 nano-seconds. If design specifications allow, higher delay can be acceptable.

Since each pair in the cable has its own unique twist ratio, the delay will vary in each pair. This variance (delay skew, discussed in the next section) should not exceed 50 nano-seconds any link segment up to 100 meters. Standards require that propagation delay for a cable be considered to be the propagation delay of the fastest pair, that is, the shortest propagation delay.

4) Propagation Delay Skew

a) Measurement Definition

Propagation delay skew (skew) is the difference between the propagation delay on the fastest and slowest pairs in a UTP cable. Some cable constructions employ different types of insulation materials on different pairs. This effect, in addition to unique twist ratios per pair, contributes to skew.

Skew is important because several high speed networking technologies, notably Gigabit Ethernet, uses all four pairs in the cable. If the delay on one or more pairs is significantly different from any other, then signals sent at the same time from one end of the cable may arrive at significantly different times at the receiver. While receivers are designed to accommodate some slight variations in delay, a large skew will make it impossible to recombine the original signal.

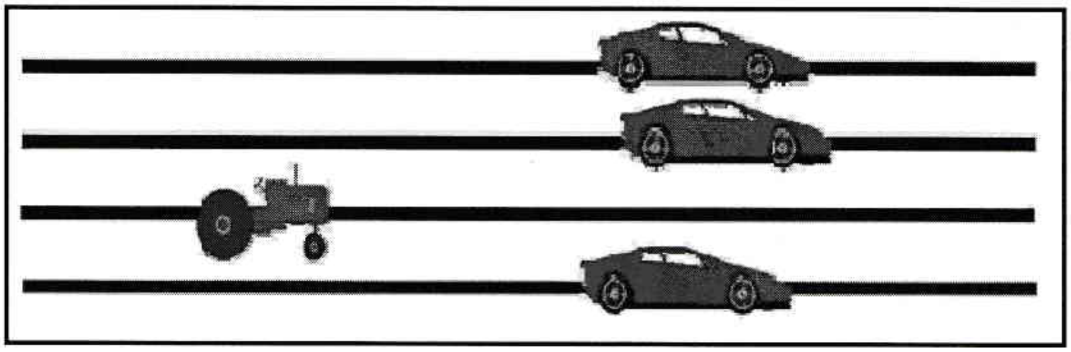


Figure 9-12 Propagation Delay Skew

b) Results Interpretation

Well constructed and properly installed structured cabling should have skew less than 50 nanoseconds over a 100-meter link. Lower skew is better. Anything under 25 nano-seconds is excellent. Skew between 45 and 50 nanoseconds is marginally acceptable.

5) <u>Length</u>

a) Measurement Definition

Length is defined as the physical or sheath length of the cable. It should correspond to the length derived from the length markings commonly found on the outside jacket of the cable. Physical length is in contrast to electrical or helical length, which is the length of the copper conductors. Physical length will always be slightly less than electrical length, due to the twisting of the conductors.

In order to measure length, a test set first measures delay, then uses the cable's nominal velocity of propagation to calculate length. Nominal Velocity of Propagation (NVP) refers to the inherent speed of signal travel relative to the speed of light in a vacuum (designated as a lower case c). NVP is expressed as a percentage of c, for example, 72%, or 0.72c. All structured wiring cables will have NVP values in the range of 0.6c to 0.9c. Similarly, if you know the physical length and the delay of a cable, you can calculate the NVP.

By convention, length is derived from the shortest electrical length pair in the cable. Because of delay skew, the length of the four pairs often appears slightly different. This is normal and no cause for concern, with the exception of significant (over 10%) variances.

b) Results Interpretation

The main concern when measuring length is that there is not too much cable in any segment. For horizontal structured cabling, this normally means 100 meters. This is because applications have been designed to support a maximum signal propagation delay, and if the link is too long, this delay could be exceeded. Occasionally, installers may leave excess cable in the ceiling or wall in anticipation of future needs. This is fine as long as it is considered part of the overall run. Note that tightly coiling this excess cable can lead to undesirable performance degradation due to additional return loss and near end crosstalk.

6) Attenuation

a) Measurement Definition

All electromagnetic signals lose strength as they propagate away from their source, and LAN signals over cabling are no exception. The loss of signal strength in the cable is attenuation. The more attenuation you have, the less signal is present at the receiver. Attenuation increases with both frequency and length.

Attenuation is measured in dB. Since it is a loss, it is usually expressed as a negative value. Thus, −10 dB is a weaker signal than –8 dB. Decibels are logarithmic, such that if any two signals are 6 dB different, one is twice the voltage of the other. Thus, a –10 dB signal has twice the voltage of a –16 dB signal, and four times as much as a –22 dB signal.

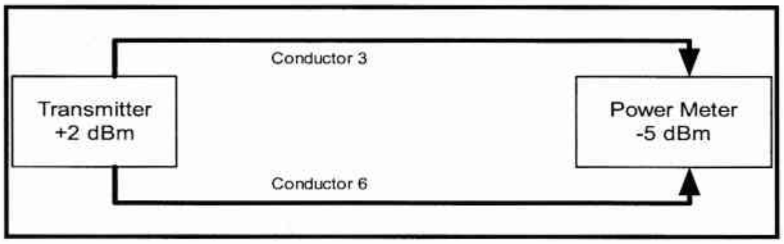


Figure 9-13 Attenuation Measurement

b) Results Interpretation

Attenuation is generally fairly linear with length and frequency. Unlike NEXT or return loss, attenuation does not exhibit oscillatory behaviour (with the possible exception of high frequencies, where insertion loss deviation may occur). The attenuation in a cable is largely dependent upon the gauge of wire used in constructing the pairs. 24 gauge wires will have less attenuation than the same length 26 gauge (thinner) wires. Also, stranded cabling will have 20-50% more attenuation than solid copper conductors.

7: Capacitance

a) Measurement Definition

Capacitance is the amount of electric field energy that can be stored between two conductors at a given voltage. For twisted pair cable, Capacitance is measured between conductors in a pair. For coaxial cable, the Capacitance is measured between the conductor and the shield.

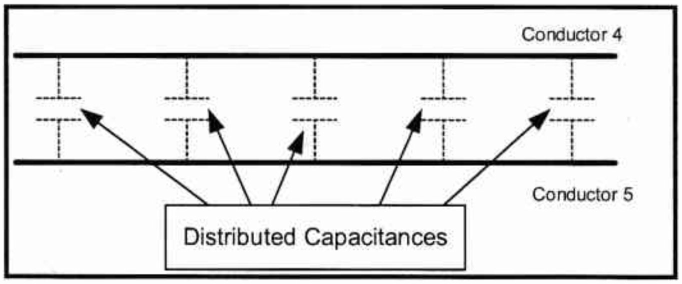


Figure 9.-14 Distributed Capacitance

b) Results

Excessive Capacitance results from the conductors of the cable being too close to each other, which may be caused by staples or cable ties crushing the conductors together. Reduced capacitance general results from excessive separation of a cable pair.

8) Insertion Loss Deviation

a) Measurement Definition

Impedance uniformity is an increasingly important parameter to understand, measure, and quantify for high speed full duplex transmission systems. The most common way to specify cable roughness or impedance uniformity has been to measure return loss. Since return loss is a reflection measurement, the amount of impedance variation measured becomes restricted at high frequencies to the first few meters of cabling. There is an interest in looking at the degree of impedance uniformity over an entire 100 meter segment in such a way as the high frequency components or roughness are not masked or attenuated by distance.

One way to accomplish these objectives is to make a through measurement rather than a reflection measurement. When insertion loss is measured on links exhibiting structural impedance variations, a ripple occurs in the insertion loss results at high frequencies (typically above 75 MHz). This ripple increases in magnitude as a function of frequency and the amount of structure in the cable. Insertion loss deviation is a measure of the worst case difference in magnitude between the expected insertion loss and the actual measured insertion loss. Insertion loss deviation is measured by first finding the insertion loss, and then computing the maximum amplitude across the specified frequency range between the insertion loss and the least squares curve that fits the insertion loss data.

The term “insertion loss” is used instead of attenuation because attenuation assumes matching impedance between the system under test and the test device. For insertion loss measurements the test device is set at 100 ohms and the system under test may have input impedance between 85 and 115 ohms.

Experiments show that return loss is not necessarily correlated to insertion loss deviation.

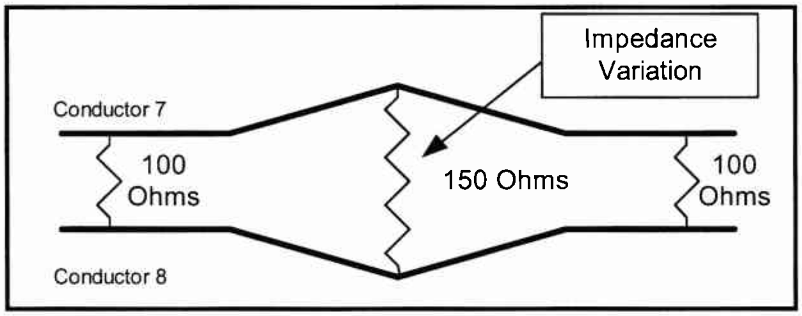


Figure 9-15 Structural Impedance Variation

b) Results Interpretation

While insertion loss deviation is under study as a Category 6 link test, there are as yet no pass/fail limits set. All that can be said at this time is that the minimum possible insertion loss is always desirable. As an illustration of insertion loss deviation, two Category 5e cables and one Category 6 cable were tested with a network analyzer. Attenuation and return loss were

measured, and then insertion loss deviation computed. All three results were plotted on the same graph to 300 MHz.

Category 5e cable shows a correspondence between an insertion loss minimum at 112 MHz and a return loss maximum. The worst case insertion loss deviation on cable C was slightly less than 2 dB. The worst case insertion loss deviation on cable B was much worse, at 8 dB, yet cable B showed better return loss performance. This suggests some structure effects are only evident at higher frequencies. Because return loss is a reflection measurement, much of these high frequency effects are not seen if they are more than a few meters from the measurement port (due to attenuation effects).

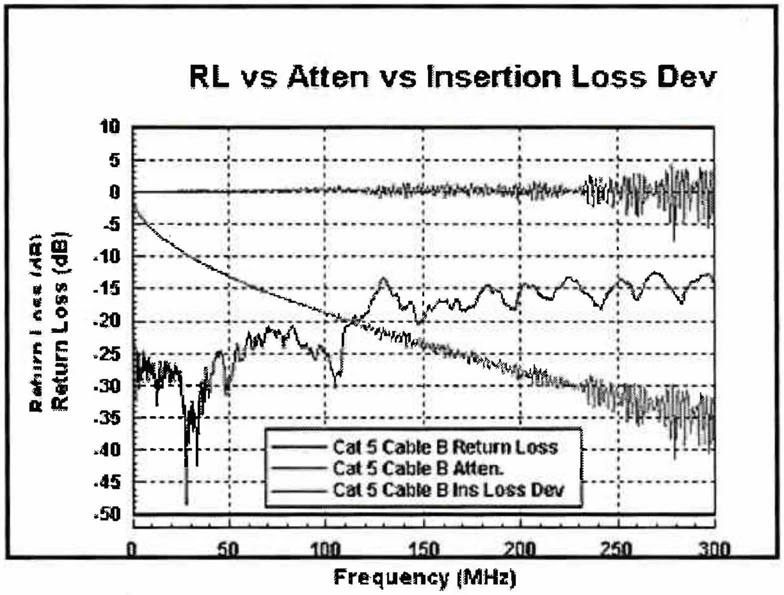


Figure 9-16 Return Loss, Attenuation and Insertion Loss Cat. 5e

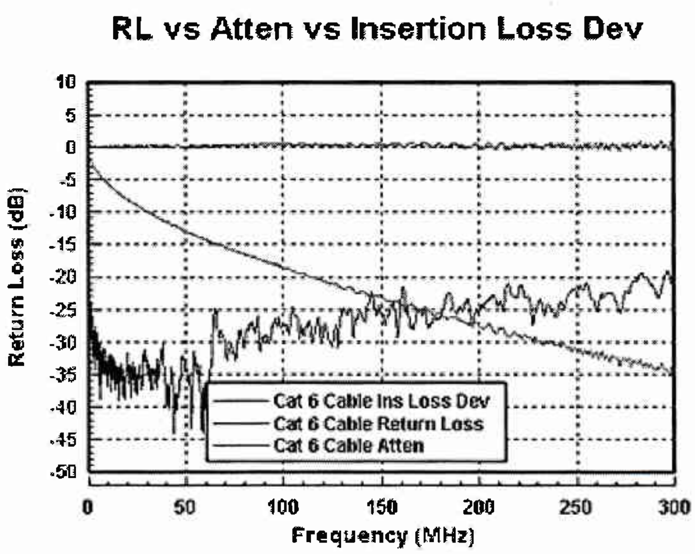


Figure 9-1 Return Loss, Attenuation & Insertion Loss for Cat. 6

9) Near End Crosstalk (NEXT)

a) Measurement Definition

When current flows in a wire, an electromagnetic field is created which can interfere with signals on adjacent wires. As frequency increases, this effect becomes stronger. Each pair is twisted because this allows opposing fields in the wire pair to cancel each other. With a tighter twist, more effective crosstalk cancellation is created, and therefore a higher the data rate can be supported by the cable. Maintaining this twist ratio is the single most important factor in any successful UTP installation.

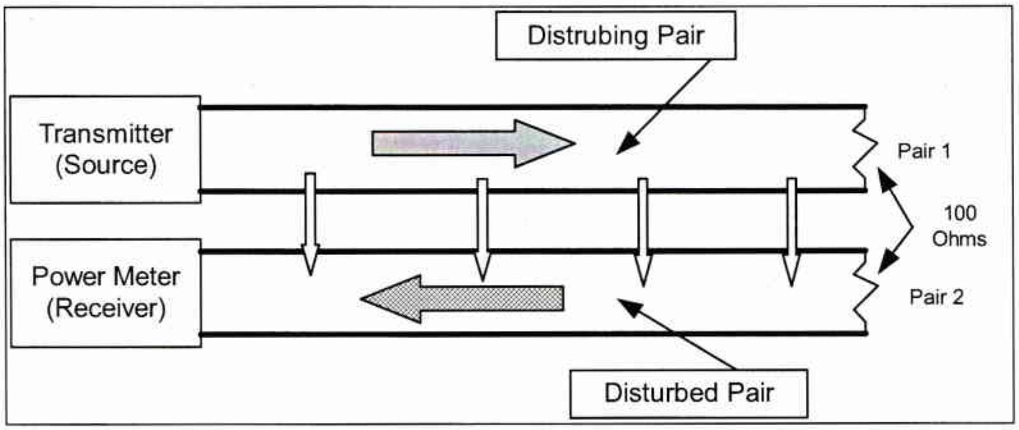


Figure 9-18 Near End Cross Talk

If wires are not tightly twisted, the result is near end crosstalk (NEXT). If you have ever had a telephone call where you could hear another conversation faintly in the background, you have experienced crosstalk. In fact, the name crosstalk derives from telephony applications where 'talk' came 'across.' In LANs, NEXT occurs when a strong signal on one pair of wires is picked up by an adjacent pair of wires. NEXT is the portion of the transmitted signal that is electromagnetically coupled back into the received signal.

b) Results Interpretation

Since NEXT is a measure of difference in signal strength between a disturbing pair and a disturbed pair, a larger number (less crosstalk) is more desirable than a smaller number (more crosstalk). Because NEXT varies significantly with frequency, it is important to measure it across a range of frequencies, typically 1–100 MHz. If you look at the NEXT on a 50 meter segment of twisted pair cabling, it has a characteristic "roller coaster going uphill" shape. That is, it varies up and down significantly, while generally increasing in magnitude. This is because twisted pair coupling becomes less effective for higher frequencies.

The field tester should compare successive readings across the frequency range against a typical pass/fail line, such as the Class D specification. If the NEXT curve crosses the pass/fail line at any point, then the link does not meet the stated requirement. Since NEXT characteristics are unique to each end of the link, six NEXT results should be obtained at each end.

10) Power Sum NEXT (PSNEXT)

a) Measurement Definition

Power sum NEXT (PSNEXT) is actually a calculation, not a measurement. PSNEXT is derived from an algebraic summation of the individual NEXT effects on each pair by the other three pairs. PSNEXT and ELFEXT are important measurements for qualifying cabling intended to support 4 pair transmission schemes such as Gigabit Ethernet. There are four PSNEXT results at each end of the link per link tested.

b) Results Interpretation

Since PSNEXT is a measure of difference in signal strength between disturbing pairs and a disturbed pair, a larger number (less crosstalk) is more desirable than a smaller number (more crosstalk). Because PSNEXT varies significantly with frequency, it is important to measure it across a range of frequencies, typically 1 – 100 MHz. If you look at the PSNEXT on a 50 meter segment of twisted pair cabling, it has a characteristic "roller coaster going uphill" shape. That is, it varies up and down significantly, while generally increasing in magnitude. This is because twisted pair coupling becomes less effective for higher frequencies.
Typically PSNEXT results are around 3 dB lower than the worst-case NEXT result at each end of the link.

11) Attenuation to Crosstalk Ratio (ACR)

a) Measurement Definition

Attenuation to Crosstalk Ratio (ACR) is the difference between the NEXT and the attenuation for the pair in the link being tested. Due to the effects of attenuation, signals are at their weakest at the receiver end of the link. But this is also where NEXT is the strongest. Signals that survive attenuation must not get lost due to the effects of NEXT.

Using PSNEXT and attenuation, power sum ACR (PSACR) can also be calculated.

b) Results Interpretation

ACR is an important figure of merit for twisted pair links. It provides a measure of how much 'headroom' is available, or how much stronger the signal is than the background noise. Thus, the greater the ACR, the better the cable structure is.

Because NEXT characteristics are unique to each end of the link, ACR results will also be different at each end. The worst case ACR results must be used.

12) Power Sum Attenuation to Crosstalk Ratio (PSACR)

a) Measurement Definition

Power sum attenuation to crosstalk ratio (PSACR) is actually a calculation, not a measurement. PSACR is derived from an algebraic summation of the individual ACR effects. There are four PSACR results at each end of the link per link tested.

b) Results Interpretation

Since PSACR is a measure signal to noise ratio, a larger number (more signal and less noise) is more desirable than a smaller number (more noise and less signal). Typically PSACR results are around 3 dB lower than the worst-case ACR result at each end of the link.

13) Far End Crosstalk (FEXT)

a) Measurement Definition

Far end crosstalk is similar to NEXT, except that the signal is sent from the local end and crosstalk is measured at the far end.

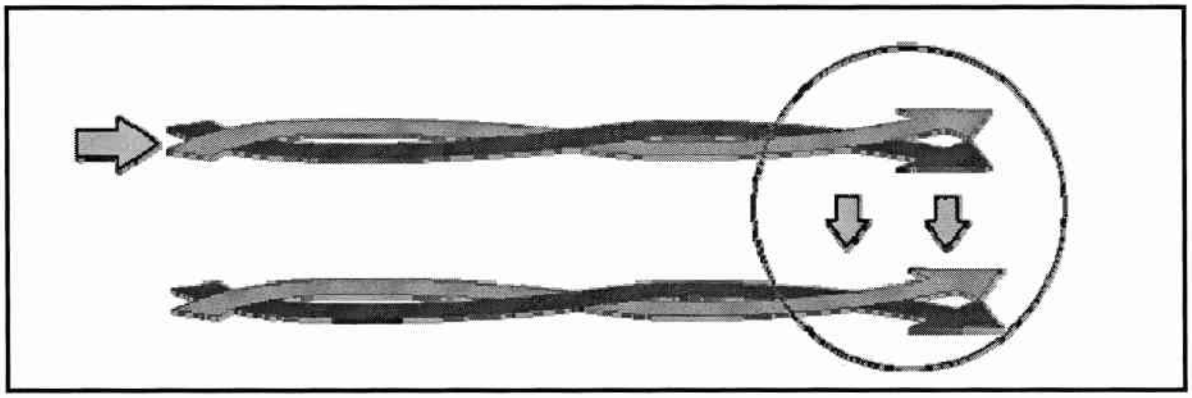


Figure 9-19 Far End Cross Talk

Because of attenuation, signals that induce FEXT can be much weaker, especially for longer cable lengths. This effect means that for a given quality of cabling, more FEXT will be seen on a short link than a long link. For reason, FEXT results are not meaningful without an indication of the corresponding attenuation on the link. Thus, FEXT is measured but rarely reported. FEXT results are used to derive Equal Level Far End Crosstalk (ELFEXT).

14) Equal Level Far End Crosstalk (ELFEXT)

a) Measurement Definition

ELFEXT is a calculated result, rather than a measurement. It is derived by subtracting the attenuation of the disturbing pair from the FEXT this pair induces in an adjacent pair. This normalizes the results for length. Consider the FEXT and attenuation measured on two links constructed of the same materials with the same workmanship, but different lengths.

50 m link 100 m link
FEXT: –45 –54
Attenuation: –11 –20
ELFEXT: –45 – (–11) = –34 dB –54 – (–20) = –34 dB

Another way to understand ELFEXT is to think of far-end ACR, which amounts to the same thing.

b) Results Interpretation

Compare the results of measurements made from both ends of the link to the appropriate ISO or TIA limits. There are 12 ELFEXT measurements made from each end, for a total of 24. This is because the attenuation can vary slightly depending upon which pair is energized. So as an example, the field tester will energize pair 1 and listen on pair 2 at the far end, then energize pair 2 and listen on pair 1 at the far end.

ELFEXT that is too high is indicative of either excessive attenuation, higher than expected FEXT, or both.

15) Power Sum Equal Level Crosstalk (PSELFEXT)

a) Measurement Definition

Power sum ELFEXT (PSELEXT) is actually a calculation, not a measurement. PSELEXT is derived from an algebraic summation of the individual ELFEXT effects on each pair by the other three pairs.

There are four PSELFEXT results for each end. PSELFEXT has the dubious distinction of being the longest acronym in the LAN cabling technology field.

b) Results Interpretation

Typically PSELFEXT results are around 3 dB lower than the worst-case ELFEXT result at each end of the link.

16) Return Loss

a) Measurement Definition

Return loss is a measure of the ratio of signal power transmitted into a system to the power reflected (i.e., 'returned'). In simple terms, it can be thought of as an echo that is reflected back by impedance changes in the link. Any variation in impedance from the source results in some returned signal. Real-life cabling systems do not have perfect impedance structure and matching, and therefore have a measurable return loss.

Twisted pairs are not completely uniform in impedance. Changes in twist, distance between conductors, cabling handling, cable structure, length of link, patch cord variation, varying copper diameter, dielectric composition and thickness variations, and other factors all contribute to slight variations in cable impedance. In addition, not all connecting hardware components in a link may have equal impedance. At every connection point there is the potential for a change in impedance. Each change in the impedance of the link causes part of the signal to be reflected back to the source. Return loss is a measure of all the reflected energy caused by variations in impedance of a link relative to a source impedance of 100 ohms. Each impedance change contributes to signal loss (attenuation) and directly causes return loss.

b) Results Interpretation

Return loss is a swept frequency measurement, and the results of a test must be under the limit line for the relevant link type (basic link, permanent link, or channel). There have been some recent developments that have shown return loss results in the field for Category 5e to be worse than expected. Follow the troubleshooting recommendations below to resolve such instances.

17) Characteristic Impedance

a) Measurement Definition

Impedance is a measure of the opposition to the flow of current. It includes the effects of resistance, capacitance, and inductance. Data cabling is commonly rated at 100 ohms impedance and this value should be constant (+/–15%) over the length and operating bandwidth of the cable.

Impedance can be specified in different ways. Input impedance and characteristic impedance are the two most common terms. Characteristic impedance refers to the impedance of an infinitely long cable. Any change in impedance within a cable causes internal reflections which lead to return loss and attenuation. Characteristic impedance is measured on cable, not links, and is a laboratory measurement. There are no published field test documents that require characteristic impedance measurement.

18) Input Impedance

a) Measurement Definition

Impedance is a measure of the opposition to the flow of current. It includes the effects of resistance, capacitance, and inductance. Data cabling is commonly rated at 100 ohms and this value should be constant (+/–15%) over the length and operating bandwidth of the cable.

Impedance can be specified in different ways. Input impedance and characteristic impedance are the two most common terms. Input impedance is the impedance seen looking into a cable. It can be mathematically derived from return loss. Return loss has become the preferred method of specifying link impedance uniformity, and so input impedance is not used in a field measurement.

19) Coupling Attenuation

a) Measurement Definition

There are some concerns about the amount of possible electromagnetic radiation emitted from active cabling, notably in Europe. One proposed method for measuring this phenomenon is via coupling attenuation. Coupling attenuation is the relationship between the transmitted power through the conductors and the maximum radiated peak power, conducted and generated by common mode currents. It is measured by energizing a pair and measuring the signal coupled into an attached absorbing clamp.

b) Results Interpretation

There are presently no standards for coupling attenuation, and it is restricted to laboratory measurements. This is because it is very difficult to isolate a single cable in a typical field environment from all surrounding EMC influences. Values of coupling attenuation depend on frequency, balance, screen material, and whether there is a single or double screen. Tests have shown that the values differ between 25-50 dB for UTP cable, 50-75 dB for a FTP cable, and 75–95 dB for a SSTP cable.

20) <u>Alien Crosstalk</u>

a) Measurement Definition

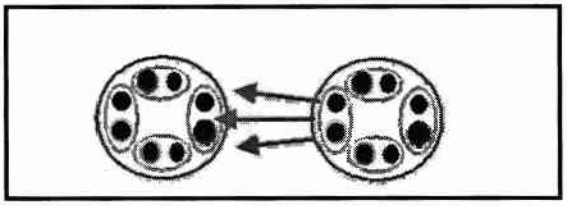


Figure 9-20 Alien Crosstalk

When cables are adjacent to each other, emissions from one cable can affect pairs in other cables. This effect is called Alien Crosstalk. It is a possible concern for UTP cables that are closely bundled together for a distance of more than 15 meters. Alien crosstalk, unlike NEXT, is an unpredictable noise source, which cannot be cancelled. Measurement of alien crosstalk is difficult because it requires synchronizing two sets of test instruments, and it is a lab measurement only. There are no pass/fail limits proposed or set at this time.

Section 9 Summary

<u>POTS Test Equipment</u>

- Toner;
  - Polarity, Continuity checks and Traceable Tones
- Inductive Chaser;
  - Identifies cables, but not exact enough to identify the Pair
- Butt Phone;
  - Polarity checks,
  - DTMF/Pulse Dialling, Loop or Ground Start
  - Various Telephone features

<u>Structured Cable Test Equipment</u>

- Cable Scanners;
  - Category Cable testing to Category 6
  - May be software updated to latest standards
  - Different Personality heads for Permanent Link, Channel testing
  - Troubleshooting abilities

<u>General Network Test Equipment</u>

- Protocol Analyzers report on;
  - Active traffic on the LAN including:
  - MAC and IP addressing
  - Collisions
  - Equipment on line and responding

<u>Structured Cable System Testing</u>

- Wire Map
- DC Loop Resistance
- Propagation Delay
- Propagation Delay Skew
- Length
- Attenuation (Insertion Loss)
- Capacitance
- Insertion Loss Deviation (Impedance Mismatches)
- Neat End Cross Talk (NEXT)
- Power Sum NEXT
- Attenuation to Cross Talk Ratio (ACR)
- Power Sum ACR
- Far End Cross Talk (FEXT)
- Equal Level FEXT (ELFEXT)
- Power Sum ELFEXT (PSELFEXT)
- Return Loss (Reflection losses)
- Characteristic Impedance
- Input Impedance
- Coupling Attenuation
- Alien Cross Talk

Section 10: Cable Testing with the DSP Cable Scanner

A: Field Testing the Structured Cable System

CITX1150 and CSST 2150

STRUCTURED CABLING SYSTEMS
FOR COMPUTER NETWORKS
&
ADVANCED CABLING SYSTEMS

Figure 10-1

Why Field Test ?

- **Do the installed cabling links meet the transmission performance criteria for present and/or future networks?**
- **Results are determined by**
  - Quality and performance of "components"
    - Cable
    - Connecting devices
  - Quality and workmanship of installation
  - EMI (routing, location) of cabling

Figure 10-2

Role of Standards

- **Component Specifications**
  - Define performance and grades of cables, connectors and hardware
  - Example: ISO IEC 11801; ANSI/TIA/EIA 568-B
- **Network Standards (Applications)**
  - Define performance requirements for all elements of a the network
  - Example: IEEE 802.3, IEEE 802.11, ATM-PHY
- **Test and Measurement Standards**
  - define measurement methodology, tools and procedures
  - Example: ANSI/EIA/TIA 568-B1

Figure 10-3

Benefits of Standards Compliance

- **Assurance that cabling system will support standards-based applications**
  - Future network applications will most likely be developed based on infrastructure standards
- **Simplify administration**
  - Reduce Total Cost of Ownership (TCO)
- **Accommodate future growth**

Figure 10-4

Frequency Specifications

- **MegaHertz (MHz) *is not equal to* Megabits per second (Mbps)**
- **MHz: A unit of frequency**
  - Describes the bandwidth of an electrical signal
  - Limited by the Physical Medium used
  - Determines the maximum frequency the signal may change
- **Mbps: A data rate**
  - Describes the rate at which digital traffic can be passed
  - A bit is binary digit (that is a logic Zero or a logic One)

Figure 10-5

Frequency Specifications

- **Bandwidth: The frequency range for which a device or transmission medium delivers a specified level of performance**
- **The information capacity of a channel in Mbps is determined by:**
  - the available bandwidth in MHz
  - the efficiency of the signal encoding
  - the sophistication of the electronics

Figure 10-6

Frequency Specifications

- Category 3 Cables are tested to 16 MHz
- Category 5e Cables are tested to 100 MHz
- Category 6 Cables are tested to 250 MHz

Figure 10-7

B: Test Background

Test Parameters – TIAEIA 568-B1

• Wire map	original TSB-67
• Length	▪
• Attenuation	▪
• NEXT	▪
• Propagation delay	spec'd in 568-A-1
• Delay skew	▪
• ACR	spec'd in 568-B-1
• Power Sum NEXT	▪
• Power Sum ACR	▪
• ELFEXT	▪
• Power Sum ELFEXT	▪
• Return Loss	▪

Figure 10-8

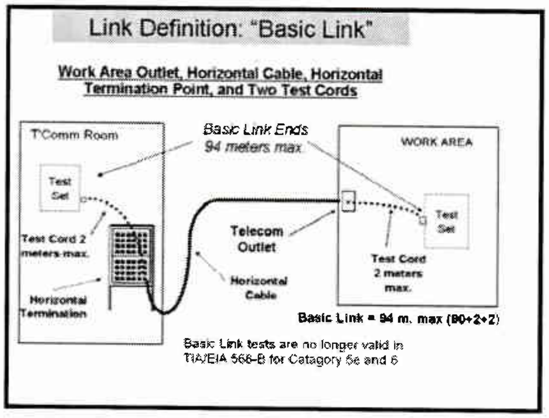


Figure 10-10

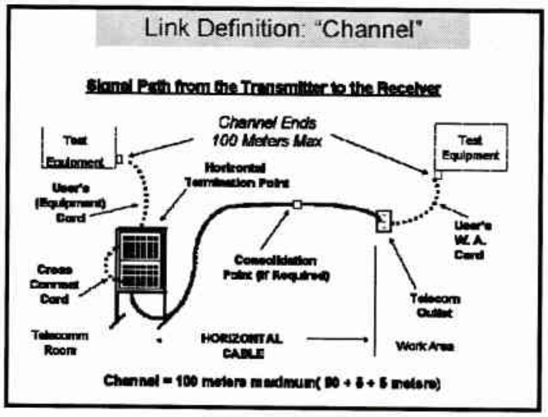


Figure 10-9

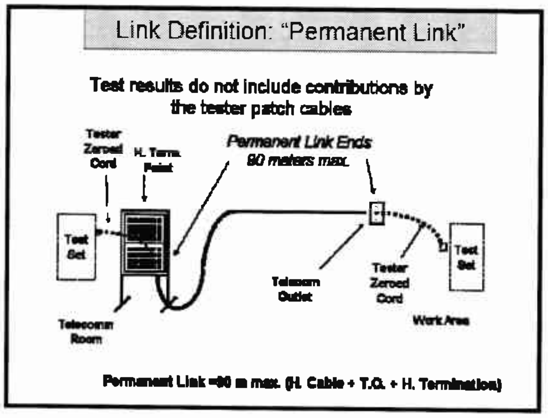


Figure 10-11

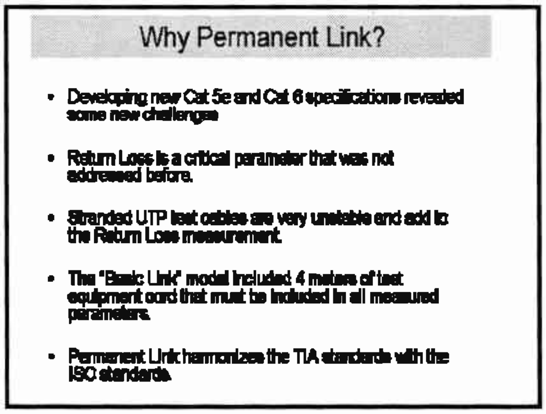


Figure 10-12

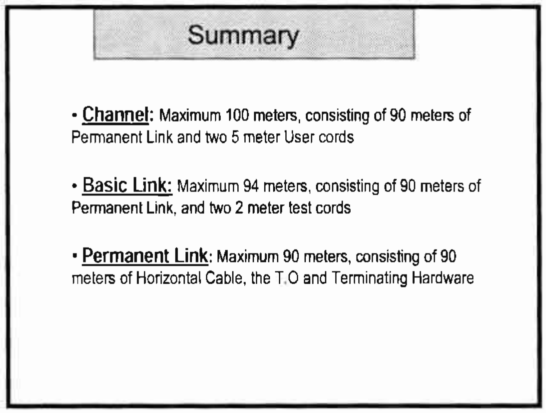


Figure 10-13

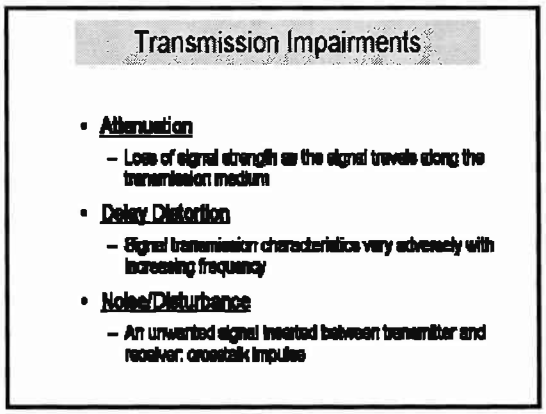


Figure 10-14

C: Test Parameters

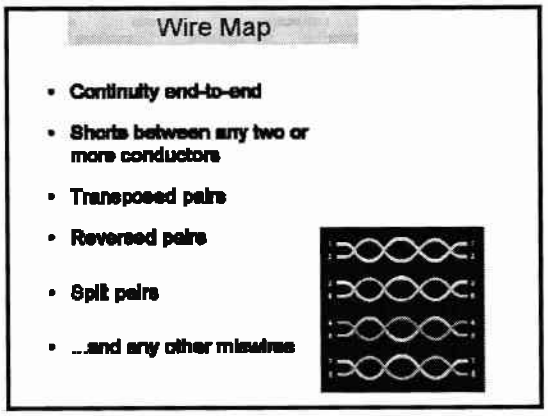


Figure 10-15

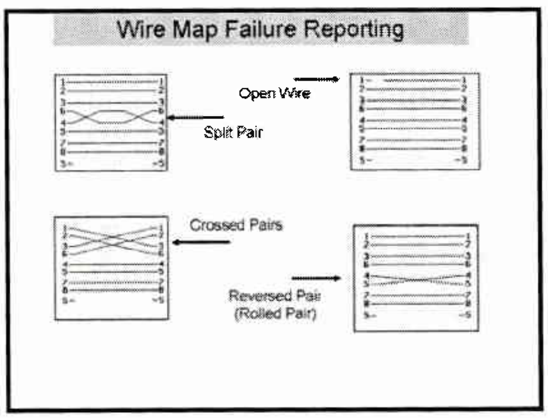


Figure 10-16

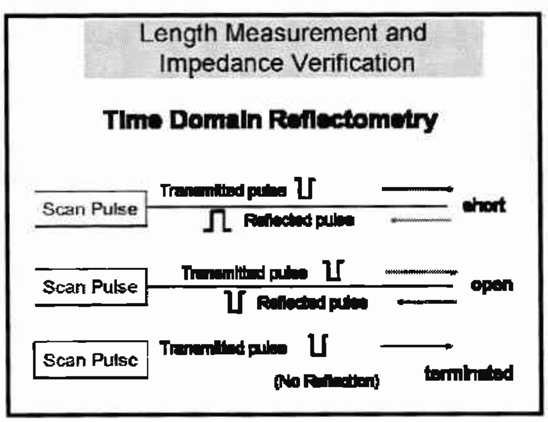


Figure 10-17

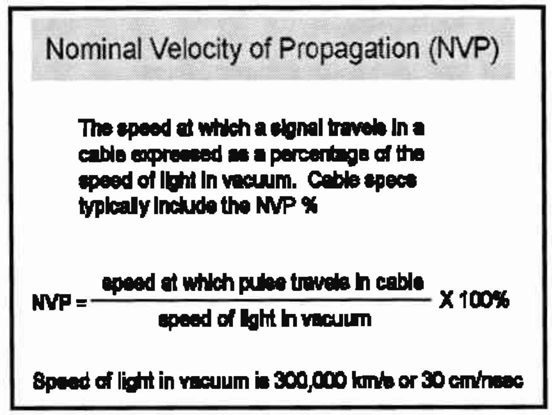
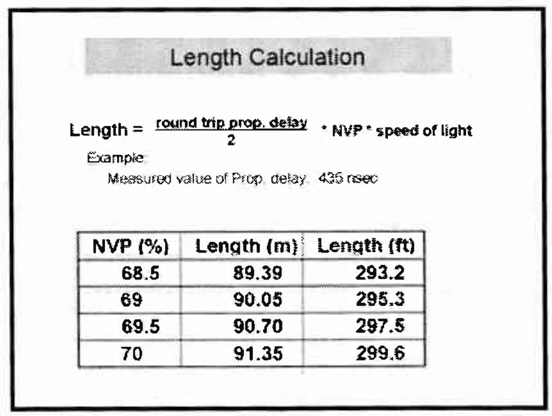


Figure 10-20



NVP (%)	Length (m)	Length (ft)
68.5	89.39	293.2
69	90.05	295.3
69.5	90.70	297.5
70	91.35	299.6

Figure 10-21

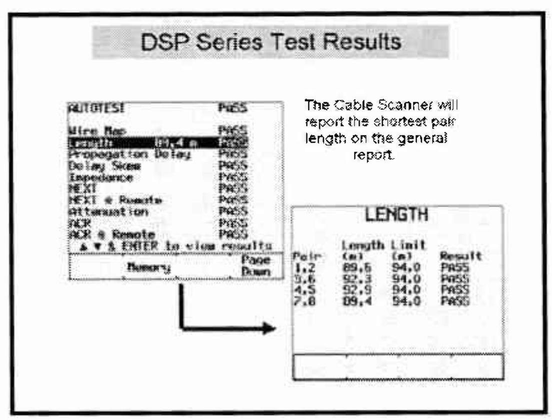


Figure 10-22

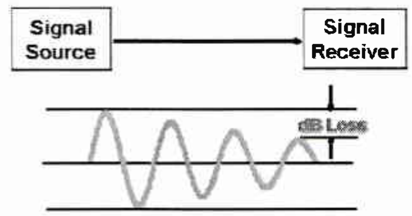
Length Measurement Reporting

- Measured Link Length
  - Calculated for shortest electrical delay
  - Measured using the Permanent Link adpater only
  - Maximum length is 90 meters
- Test Limit (PASS/FAIL)
  - Maximum allowable link length *PLUS* 10%
  - Calculated for shortest electrical delay

Figure 10-23

Attenuation

The amount of signal "LOSS" in the transmission link (expressed in dB)



Attenuation increases with Frequency & Distance

Figure 10-26

Attenuation

- **Sources/Causes**
  - **The electrical characteristics of the cable materials and its construction**
  - **Insertion losses due to improper termination (IDC)**
  - **Reflections due to impedance mismatches**
  - **As temperature increases so does attenuation**
- **Effect**
  - **Above a certain amount of loss, the cabling link may not reliably transmit network data**

Figure 10-24

Attenuation as a Function of Frequency

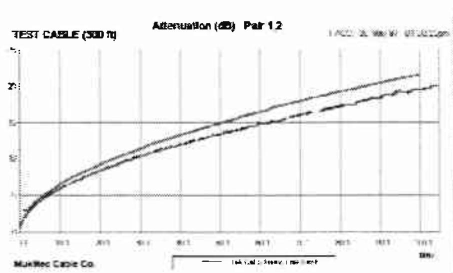


Figure 10-27

Attenuation

- Each decrease of 10 dB indicates a power loss by a factor of 10
- Remember that decibels indicate a ratio
- dB = 10 log (P_{out} / P_{in})

Ratio	*Decibel*
1/1	0 dB
1/10	-10 dB
1/100	-20 dB
1/1000	-30 dB
1/10,000	-40 dB

Figure 10-25

Attenuation

- Measured in decibel (dB)
- Decibel is a logarithmic expression of a (power) ratio
- Each loss of 3 dB indicates a loss of ½ the power

Ratio (% Power Remaining)	*Decibel*
1/1	0 dB
½ (%50)	-3 dB
¼ (%25)	-6 dB
1/8 (%12.5)	-9 dB
1/16 (%6.5)	-12 dB

Figure 10-28

Attenuation Measurement Reporting

- PASS
  - Highest measured attenuation and frequency at which this occurred
  - Test limit at this frequency
- FAIL
  - Measured attenuation and frequency at which this occurred
  - Test limit at this frequency
- Gray Zone
  - Measured value within the accuracy of the test set
  - See slide # 85 for details

Figure 10-29

Impedance Anomalies

- The DSP cable testers reports an "anomaly" if:
  - It detects a "significant reflection"
    - Determined by Threshold value in Setup
- An anomaly is found during the length and TDR tests
  - A reflection indicates a change in the impedance of the link under test
  - The distance to the anomaly and a Warning test result is reported
  - Impedance is measured in ohms (Ω)

Figure 10-32

Attenuation View Plot

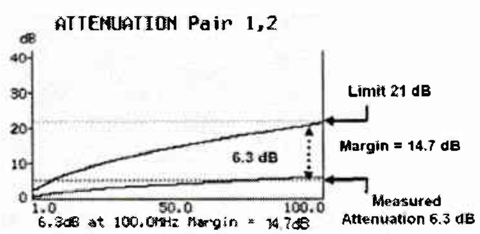
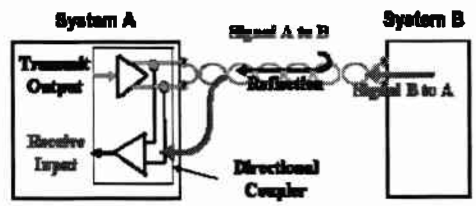


Figure 10—30

Effect of Return Loss

Full Duplex LAN systems



Desired signal = attenuated signal from other end.
Noise = reflected signal on same wire pair.

Figure 10-33

DSP Series Test Results

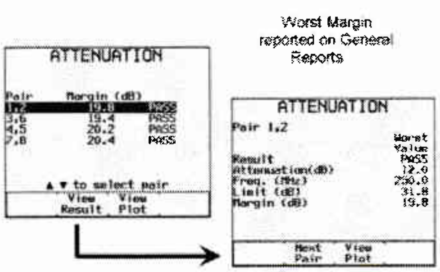


Figure 10-31

Return Loss

- A measure of reflected signal power over the frequency range of interest
- Result of variations in Characteristic Impedance and Impedance mismatches
  - Structural variations due to the cable manufacturing process
  - Connectors
  - Installation

Figure 10-34

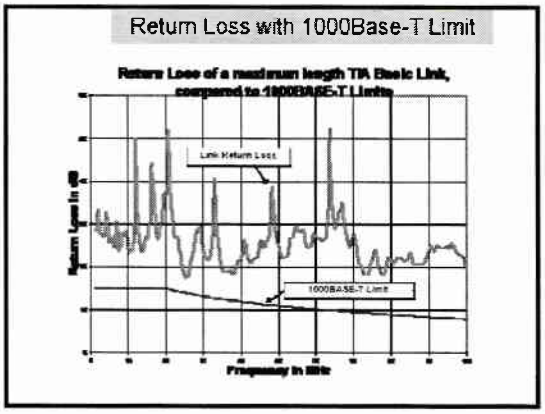


Figure 10-35

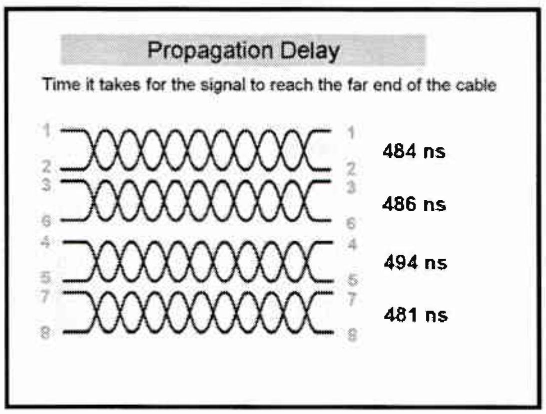


Figure 10-36

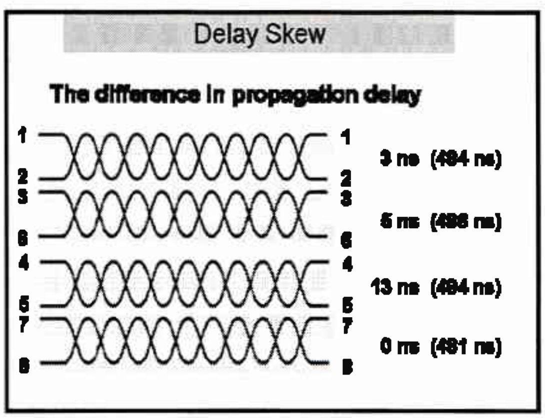


Figure 10-37

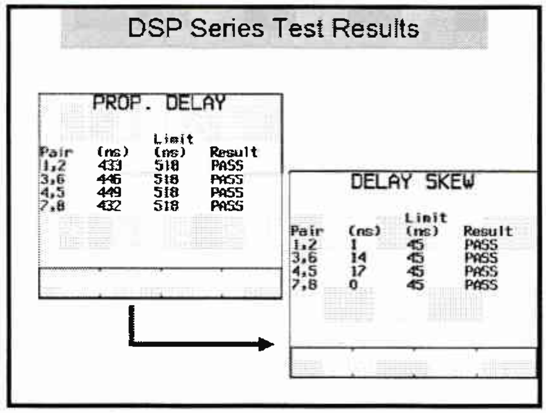


Figure 10-38

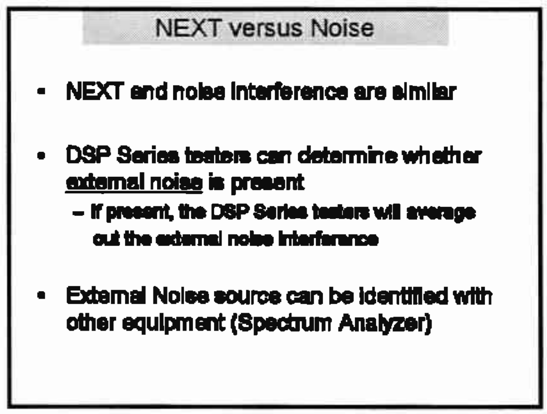


Figure 10-39

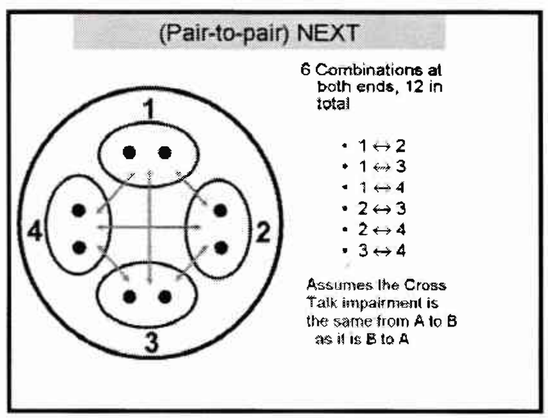


Figure 10-40

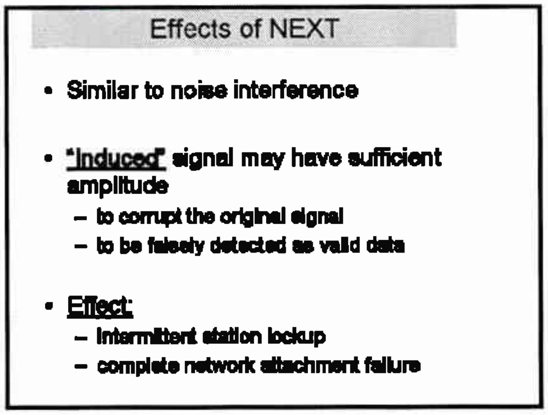


Figure 10-41

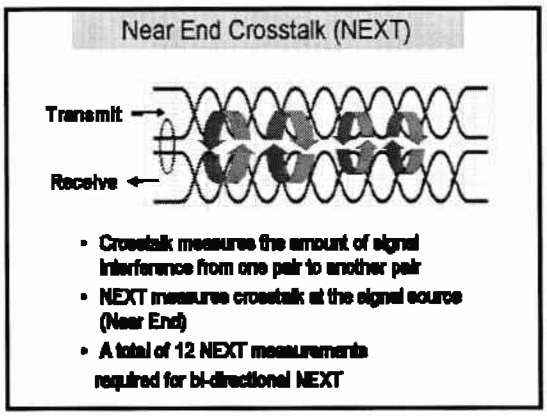


Figure 10-42

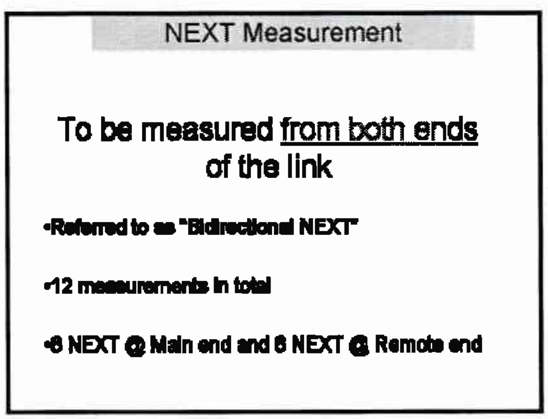


Figure 10-43

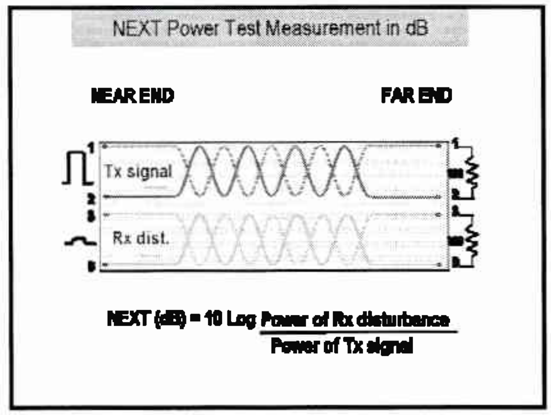


Figure 10-44

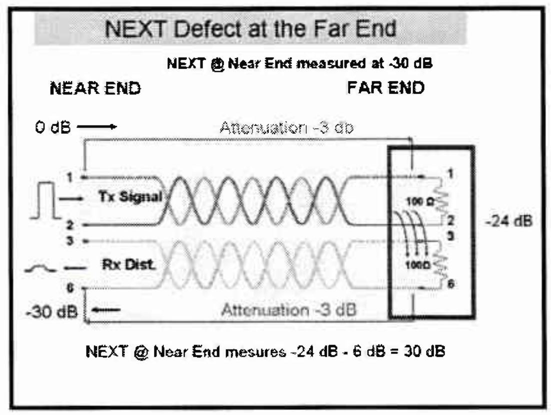
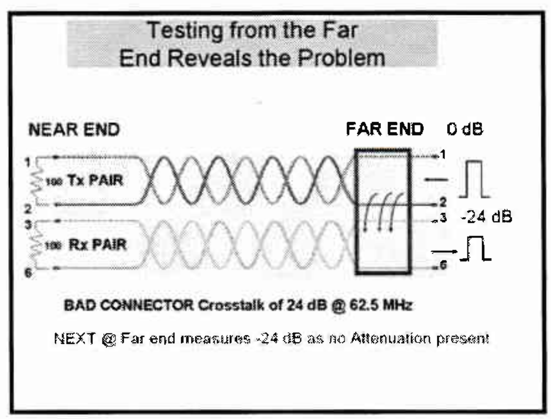


Figure 10-45



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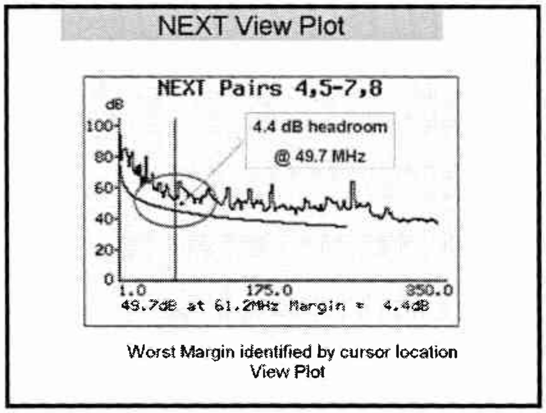

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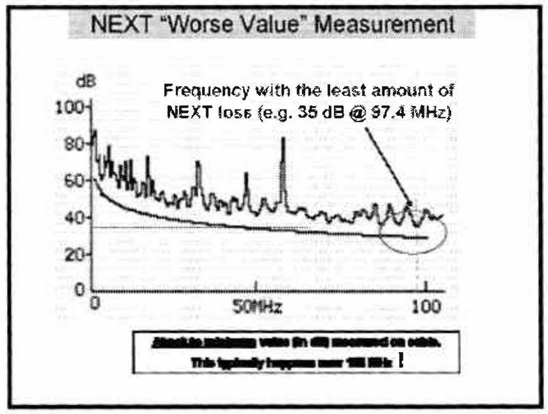

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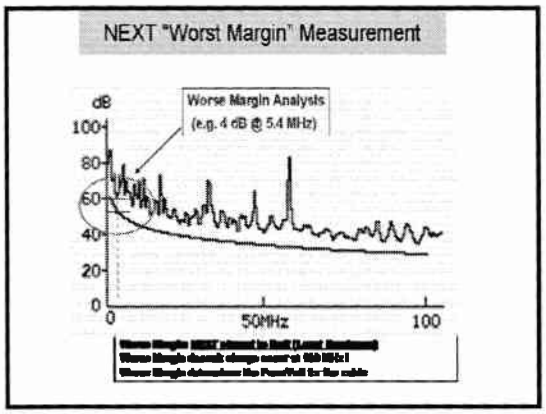

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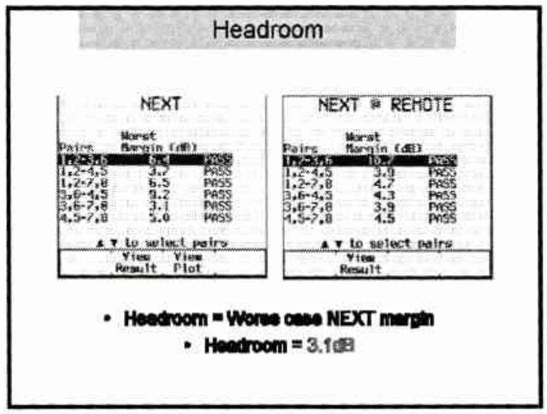

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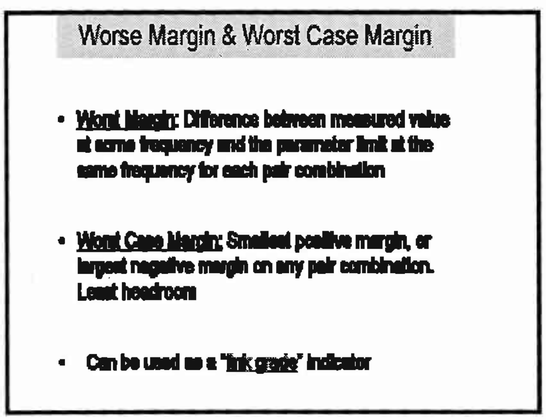

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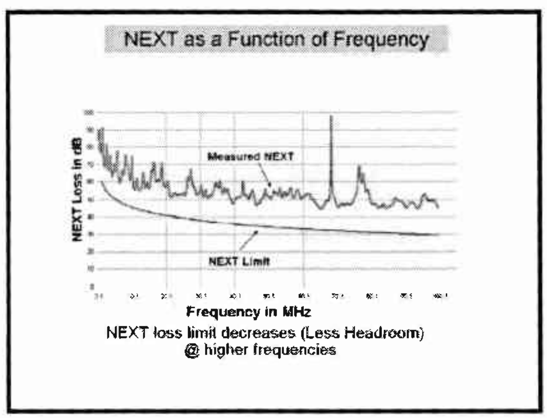

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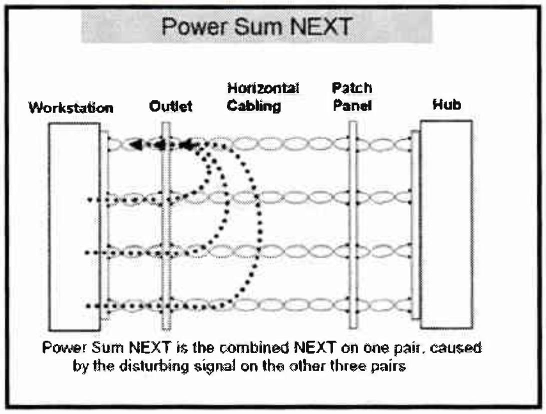

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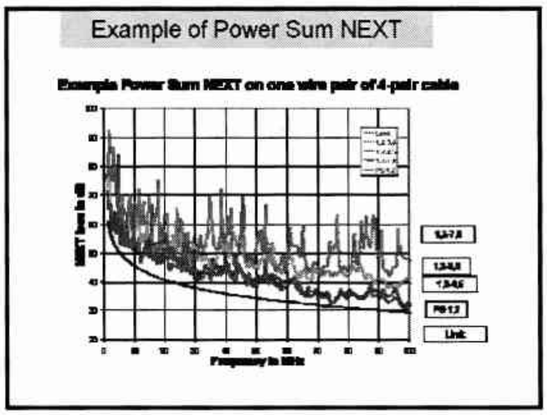

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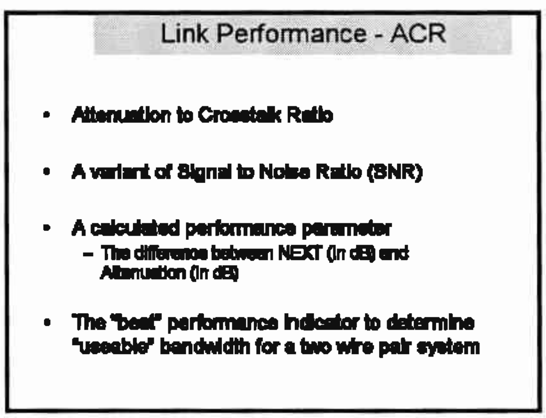

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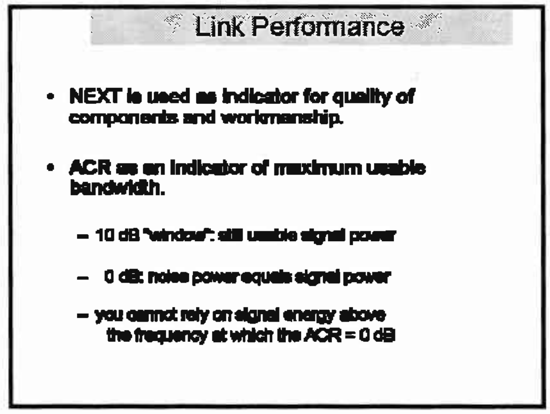

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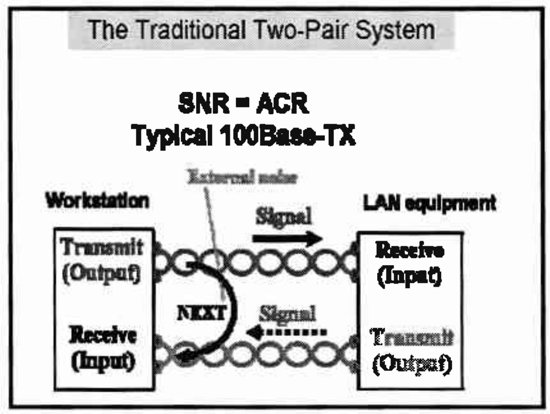

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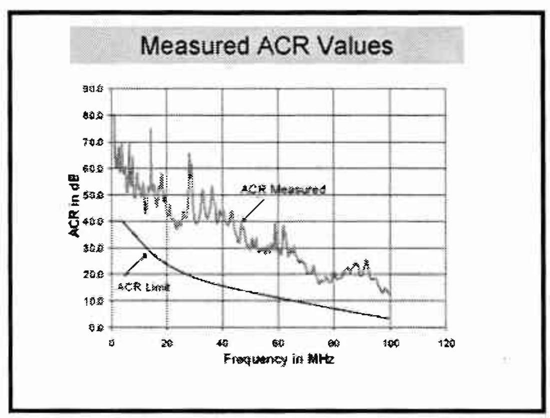

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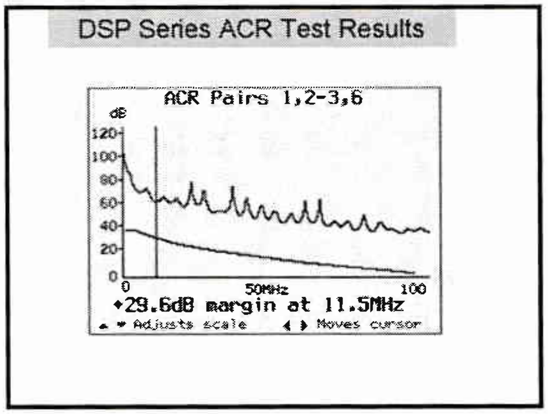

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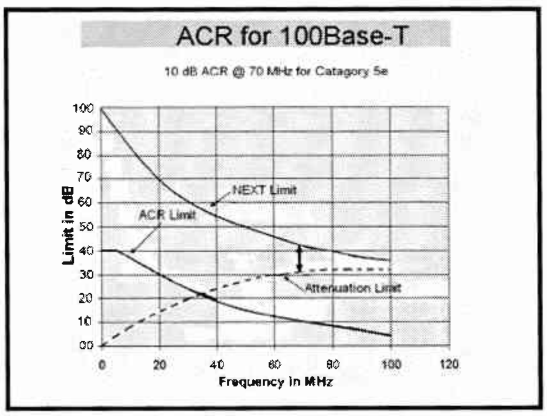

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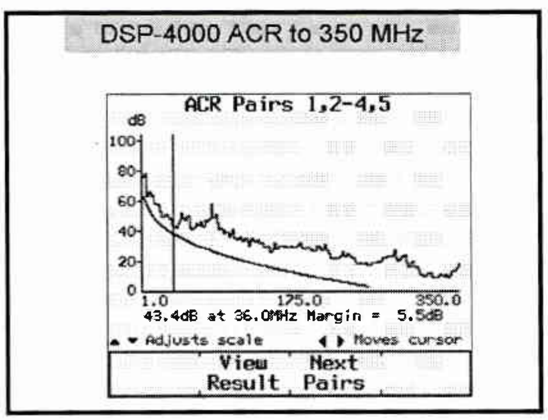

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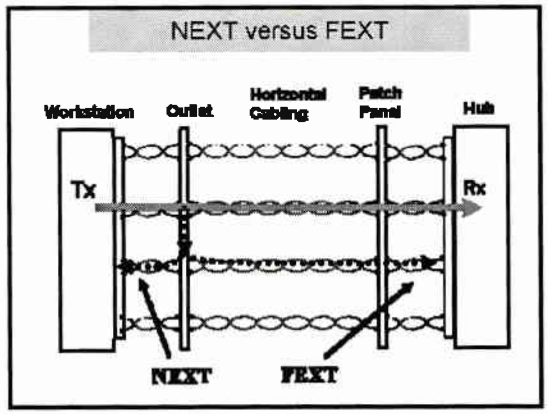

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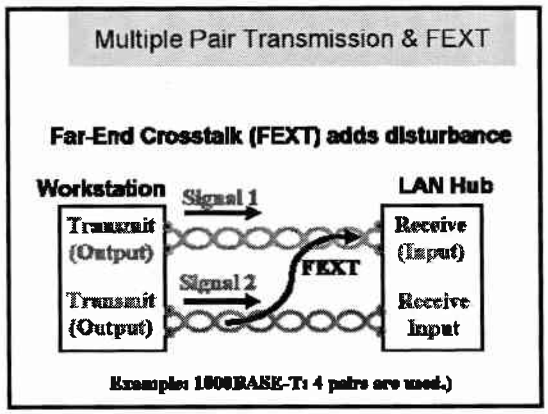

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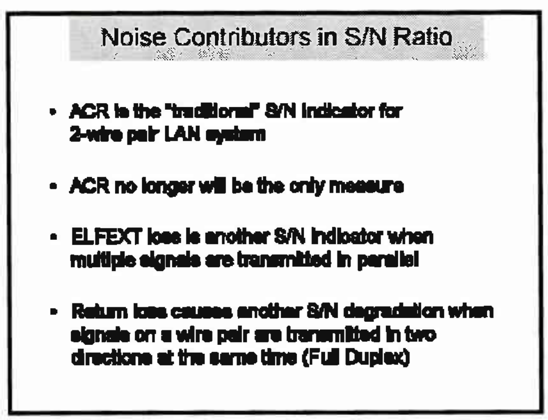

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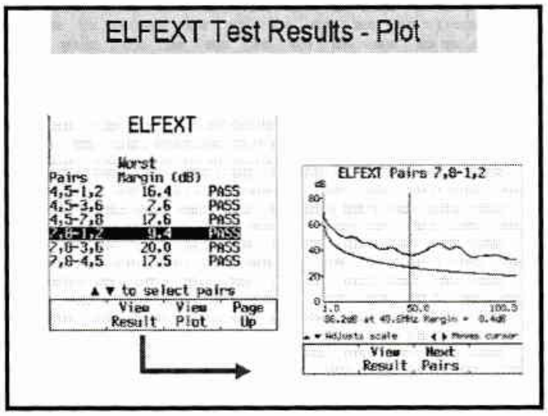

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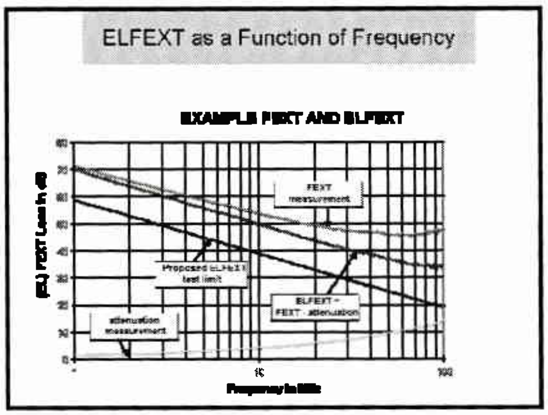

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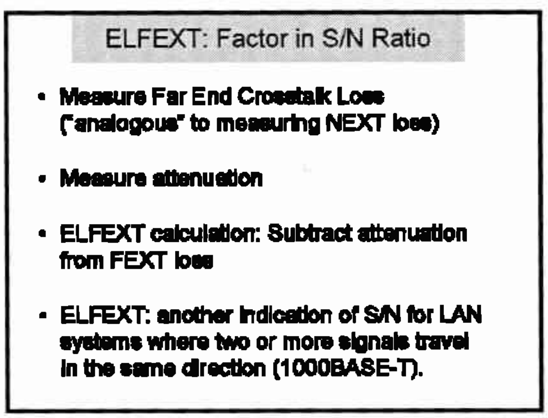

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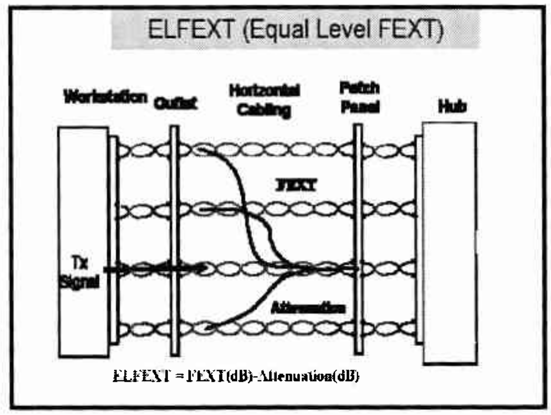

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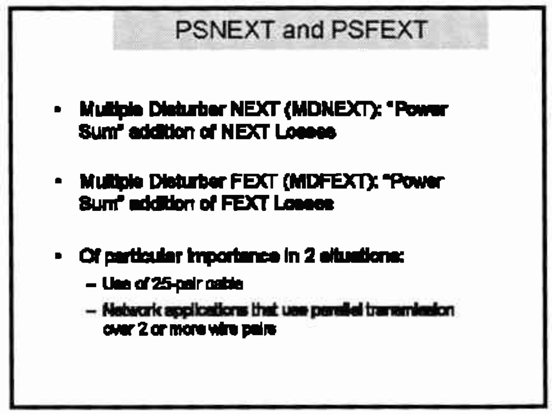

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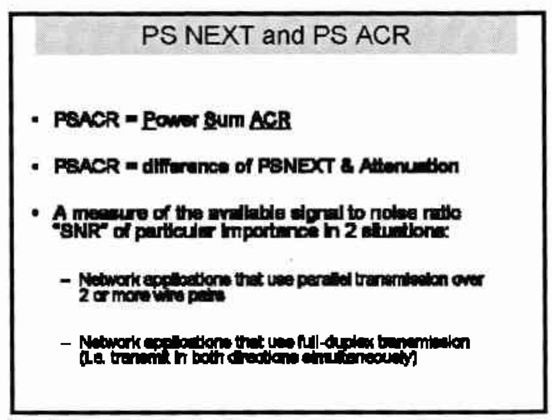

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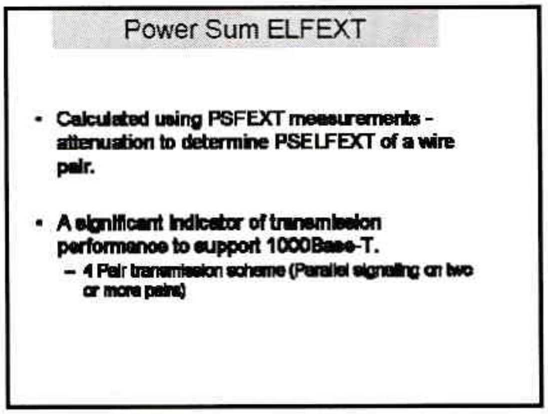

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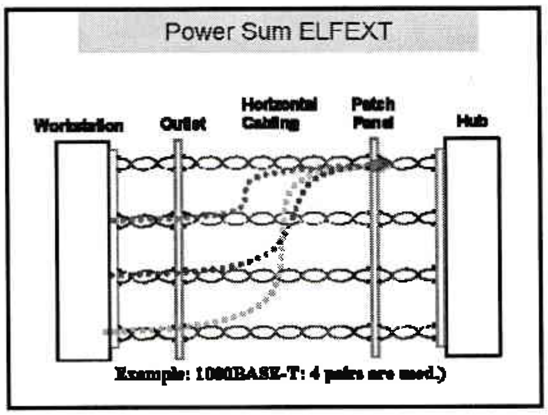

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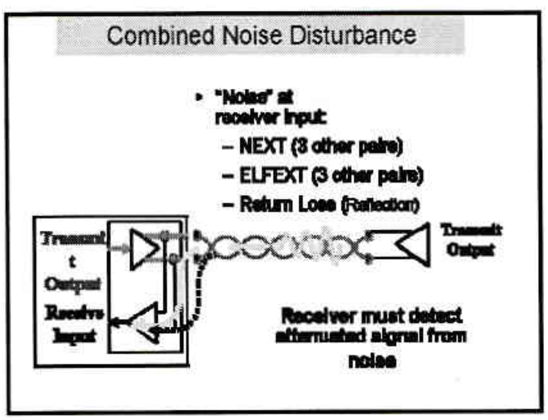

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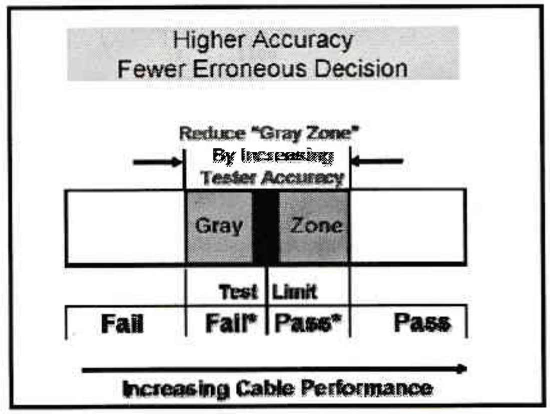

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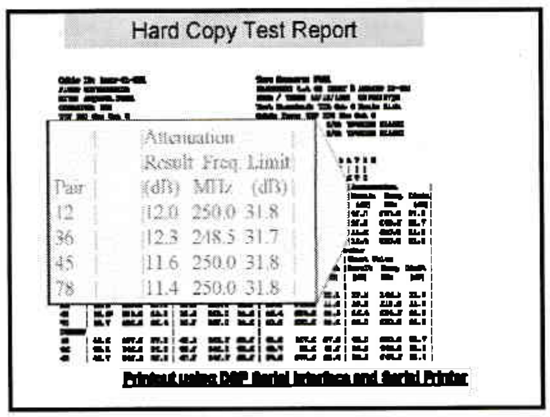

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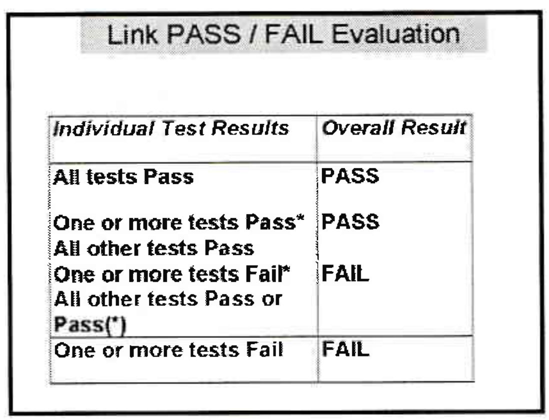

Individual Test Results	*Overall Result*
All tests Pass	PASS
One or more tests Pass* All other tests Pass	PASS
One or more tests Fail* All other tests Pass or Pass(*)	FAIL
One or more tests Fail	FAIL

Figure 10-74

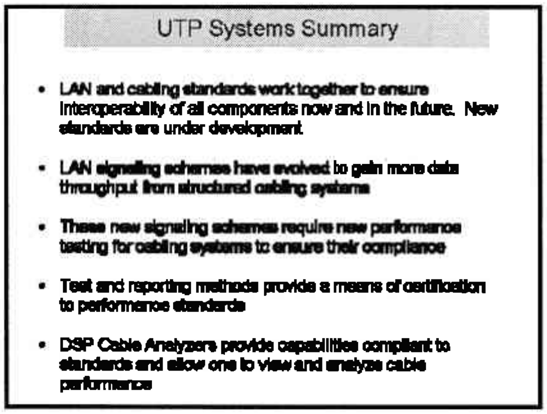
UTP Systems Summary
LAN and cabling standards work together to ensure interoperability of all components now and in the future. New standards are under development
LAN signaling schemes have evolved to gain more data throughput from structured cabling systems
These new signaling schemes require new performance testing for cabling systems to ensure their compliance
Test and reporting methods provide a means of certification to performance standards
DSP Cable Analyzers provide capabilities compliant to standards and allow one to view and analyze cable performance

Figure 10-75

Section 11: Troubleshooting

A: Troubleshooting Principles

The troubleshooting process can be understood at its simplest level as a set of steps designed to determine the source of a problem and the corrective measures required to restore the network health. Like learning to play a piano, however, the though processes which are required to develop effective troubleshooting techniques require practice, concentration, and reflection. The best tool in troubleshooting is the technician's knowledge of the network in its healthy, error free state. If you do not understand how a system reacts when it is working properly, do not expect to understand the multitude of impairments which could occur.

For this reason, the first step in troubleshooting begins well before the trouble does, as the Audit of the functioning network. Then, when a network trouble develops you will have the background in place to determine what has changed, and to evaluate why that aspect may have changed.

The next step is to have a "baseline" study complete in the healthy network. Determine the normal operating parameters of the network, the user of each outlet and the network protocols or telephone features they use. The Network Interface Card Media Access Control (MAC) address and physical termination address for telephones should be recorded for entry into the Reports of the TIA/EIA 606 documentation.

Next, a survey of network protocols and logical address should be completed. In the case of the network protocols, the diagnostics of the network operating system in use have to be utilized. This requires a thorough understanding of the network operating system used. Remember to record the logical and physical addresses of all equipment on the network.

The last step is to ensure all the various log files contained in the work stations and serves are turned on, and logging information on the operation of the network software.

B: Audit of the Network

It is a rare network install company which provides the client with even a portion of the network documentation recommended by the TIA/EIA 606 document. Normally, the best the client can expect is a record of the cable tests, if the category certification tests where included in the original contract, and a bare minimum of outlet and hardware termination identification.

During the network turn-up, a good Network Administrator would keep a paper record of the work she/he did while getting the various cable elements cross-connected so the users could get on-line and on with their work. Assuming all stations are up and working correctly, it is now time for the Network Administrator to turn to performing a complete Audit of the networks, which can be used as a "base-line" for any future troubles or upgrades.

The steps in completing a network audit include;

a) Network Documentation as per the TIA/EIA 606
b) Evaluation of the Physical Layer
c) Evaluation of Data Link Layer
d) Evaluation of the Network Layer.

C: Network Documentation

A complete and accurate set of Records, Reports, Drawings and Work Orders, as described in the TIA/EIA 606 document, will form the basis of any network audit. Any physical network is like a tree, and the best place to start your documentation is at the root, or in this case, at the Entrance Facility.

List all communications cables, their size, ownership, functions and the Carrier Company's identification numbers, such as their lease or cable number. Note things like grounding conductors, conduit (those going outside as well as the inside conduit) and any identifiers the cable installation company have affixed to the cross-connection blocks or cables. If the cables were not labelled, record the distance measurement (generally a unique value) on the cables as an initial way of identifying the other end of these cables, and provide your own identification. Record hardware termination blocks, types of blocks and any identification provided. Do not worry about the individual pairs at this time, as you will have to produce a record of the cables before the pairs can be individually identified. Again, if no identification provided, create one your self. Try to use encoded identifiers, identifiers which provide you with a location as well as a type of element. Collect all the information you can at each location you visit.

Draw a rough view of the entrance facility, in plan and elevation views, indicating the conduits, cables, protection blocks, cable identities etc. Combine with any other documentation you produced, and keep this information together.

Next, visit the equipment room. Determine which cables are coming from the Entrance Facility, which are going onward to the Telecommunications Rooms. Deal first with the incoming cables. Are all of the cables from the Entrance Facility present, or are some going elsewhere in the building? If the cables are not identified in any manner, check the distance measurements to determine the cables involved, and apply your own identifiers to this end of the cables. Note any cables from the Entrance Facility which are not present. You will probably find these cables in some other space.

Record all the equipment in this room. What type of termination hardware is present? Is there a telephone switch present? How about Wide Area Network terminations such as modems or multiplexing equipment? Is there a grounding busbar present? How about grounding conductors? What are the conduits, and what is their fill? This information is important to be able to plan future expansions.

Finally, inspect the onward cables, those going to other locations in the building you have not visited. Again hardware termination blocks, cables and/or cable length measurements and conduits should be identified.

Follow the same procedure to locate all the equipment, grounds, cables and cross-connections and equipment in every telecommunication space you are responsible for.

The last stage in the initial audit is to visit every work area under your administration to find all the work area outlets. Here a simple floor plan is required, so that the location, identity and category of each outlet can be recorded.

Once the initial audit survey is completed, produce a set of records and diagrams as required by the TIA/EIA 606 document. Include all the required information and required linkages described in that document. If any information was missed, return to the space to collect or create that information.

D: Baseline studies of the Network

Once the "map" of the physical network is completed, the next step is to look at the healthy network, and to record the parameters and status of the various sub-systems in the network. Here there will likely be a separation between the Local Area Networks, the telephone system, and the Wide Area networks.

The Local Area network baselines should include information such as the populations in each sub-network, and their members. An effective network ensures that traffic is kept to a minimum. A rule of thumb for any communications is that 80% of the traffic is local (which may mean to physical neighbours, or to members of the same job classification), and 20% is remote (i.e. to distant stations, or to members of different job classification.)

As far as the network is concerned, an effort should be made to ensure that members of the same job type (e.g. salesman or operations) are kept on separate subnets. Studies have determined that sales people are more likely to talk to other salespeople rather than operations or managers. Likewise managers talk (mostly) to each other, as do the operations people. Hence the 80/20 local/remote communications rule of thumb.

The process of analyzing the network includes determining the Top Senders on the network. This could be users which require a large part of the network traffic. An association between the network addresses, the MAC address and the user, or at least the work station name, would be then created.

Alarms and indicators such as lights and traffic indications on the various pieces of equipment should be recorded. These go/no go indicators are useful in determining call set-up and status. Look up the meaning of each of the lights, and record it in your documentation. It is not the time to look for information when the network is in trouble. Instead, plan ahead for those times, and be prepared for them.

If your operating system or third party software permits, run and record the results from the network statistics, especially the Collision and Error statistics, and the other utilities. In the case of Token rings, establish the stations identification in ring order and to record such protocol characteristics as the token rotation time, and station Ping times. Once again, the idea is to see how the network operates when it is healthy.

Baseline studies are also used to back up requests for increased capacity and to monitor the network's health. An ounce of prevention is worth a pound of repairs. Are the users making higher demands on bandwidth? Did a new application skew the response times? Did a set of users locate a video streaming source to watch the World Cup Finals? Are there issues supporting traffic at certain times of the day, or certain days of the week? Are these legitimate "busy" periods (e.g. inventory times, server mirroring times etc.) Just like a car engine, if you never check the oil sooner or later the engine will seize up on you. Maintenance is part of your job, not just restoration. Use your time wisely when all is sailing smoothly.

E: Protocols and Software

A thorough understanding of the protocols used in the network operating systems is mandatory: a person cannot hope to untangle the possible permeations of a network trouble without knowing the relationship between the various protocols which may be running on a network at any particular time.

In general, there are three places a problem could occur; a cable fault, which may affect one or many users, an equipment fault, which may or may not be critical, and a software fault, either in the application, or in the communications protocols. The first thing to sort out is which of these three areas is the problem most likely located. Many symptoms can have their problem source in any of these areas. Your job as a troubleshooting is to confirm what is working, as well as what is not working.

What is the network doing, and what is it not doing? What information is the network not finding? Is the source of the communication faulty, or is it the destination? Two ends are active in any communication, and both must be operating correctly for the communication to happen.

These questions, and many more, must be asked and answered in troubleshooting, and this means you must have a good understanding of the system when it is working, before you can hope to become efficient at locating problems when they occur. Study the protocols in use on the network, and learn how they interoperate. Keep a record of logical and physical accesses, mapped to each other. Keep a list of the work group names, and their members.

F: Log Files

Most software contains a number of utilities which, once understood and mastered, will help the Network administrator to resolve bottlenecks and network impairments. One facet not to be over looked is the use of Log files. Once Logging is turned on, a time-based system of alarm and fault monitoring can be run in the background, reporting on events and errors as they happened.

When a fault occurs, searching the appropriate log files may reveal the source of the fault, and point to the corrective measures required. Often, these log files are not fully documented, so careful reading of the Read Me files and perhaps a search for *.log files may be required to locate them.

Another type of log file is the one the Network Administrator has to establish as a paper trail. This would include all work orders, trouble tickets and Move/Change orders for the Network. Networks can be particularly sensitive to changes, and any modifications or upgrades to the software of the Network should be fully documented. Each server can have its own log file, recording all changes, additions and faults. If your server hiccups, you want to record the event and find out what the problem is.

When faced with a troubleshooting task, the Network Administrator should try to log every step they use in their troubleshooting process, as this will assist her in resolving the fault, and in future troubles. Remember that troubleshooting is a learned process, and the more you analyze and reflect upon the steps you took to restore the network to health, the better your troubleshooting abilities will become. Keep a clip board or a steno pad with you on all trouble calls.

G: 6 Steps to Troubleshooting

Step 1: Collect All Available Information

Verify the trouble yourself; do not take the user's description. Remember that you are the network expert, not the user

What has changed, added or been removed? If the station has never worked the troubleshooting path followed is different than if the station just stopped working.

Is the problem always present, or is it intermittent? If intermittent, is there any pattern?

Start a Trouble Ticket, a paper document with all pertinent information on it, and record the processes and tests you perform along the way.

Step 2: Localize the Trouble

How extensive is the problem? Does it only affect one user, a group of users, all the users?

Is the problem a local access (e.g. can not access another user) or WAN access (can not access the Internet)?

Record the addresses, (User name, Work Group, NIC address, IP address) of affected work stations.

Step 3: Isolate the Trouble

Could the problem be caused by software, hardware or the physical channel?

Simplify the connections by reducing to a minimum (e.g. can not talk to any other stations? Try using a roll cable to connect to the nearest working station.)

Assume only one problem exists, and figure out what one problem could produce all the symptoms you have seen.

Step 4: Correct the Specific Trouble

Remember that the symptoms are **not** the problem; they are a manifestation of the underlying problem.

Assume only one problem exists, and test your hypothesis. If you think the Work Area cord could be the trouble, replace it. If that does not fix the trouble, **put the original back in**!

Record any changes on the trouble ticket before you do them! For instance record the current IRQ and I/O ports before changing them. You want to be able to restore the station or network back to its original condition if the change you made has no effect on the problem.

Step 5: Verify the Trouble Has Been Resolved

Once the trouble appears fixed, see if you can cause the trouble to come back. The W.A. cord in step 4 fixed the trouble? Then put the original back to see if the trouble comes back.

Simply reseating a daughter board or cycling the power could remove the cause of the trouble.

Step 6: Record the Outage and Fault Resolution in Your Log

After the user is back in service, review the steps you took to diagnose the trouble. Troubleshooting is a learned art, and requires reflection on the part of the technician.

Briefly record the basic information into your standing Trouble Log.

File the Trouble Ticket under the symptom the user or the fault, whichever way is the easiest for you to find at a later date.

Follow up the next day to confirm the user is still ok.

H: Troubleshooting Hints

a) Check the easy stuff first

Start your troubleshooting with the mindset that the trouble is a simple one, and that only one fault exists. No in or out from a work station? Is the station powered up? Is the work area cord plugged in? Can you get out? If you suspect a software hang-up, try re-cycling the power (i.e. a "cold boot" involving a clean shut down, power off and on and re-load). Remember that a Restart, that is a "warm reboot" does not recycle all the cards in the system. Do not rip apart the tower to check suit-case straps on a daughter board...unless the station has not worked since that board had been installed.

b) Divide and Conquer.

A network is like a chain, where many individual links have to be correctly working before communication can occur. Rather than check each link one after another, go to a mid-point, and check there.

Say a user is unable to access the server. Possible troubles could be the software stack, the NIC card, the channel to the Hub, a bad user port or server port on the hub, etc. First question to ask is "Can the other stations reach the server?" If yes, we presume the channel to the server is okay.

Before verifying the application, addresses, NIC cards etc., the first test may be to place a known good PC (perhaps your laptop) on the suspect channel. If your laptop can access the server, the trouble lies in the user's work station. If the laptop can not access the server, look at the physical links and the hub port. Try a new work area cord, then a new hub port.

c) Look at the problem from different viewpoints

Network issues like collisions take on different appearances from different locations on the network. Do the collisions appear as local, remote or late collisions? Does the problem affect one part of the network more than another? Then monitor both the good and the bad sections with your software. Is the user unable to connect to another station using Novell, but has no problem with NetBIOS?

Remember which way you are checking. The divide and conquer process for example permits the technician to verify the incoming signal is good (the monitor process), and to check the outgoing signal (the insertion process).

d) Swap outs

If you suspect a piece of hardware, swap it out with known good hardware. It is generally a good idea to power down the equipment if possible, always use an anti-static strap, and never touch the components or conductive traces. The static from your body can permanently damage some sensitive devices. Spare boards should be kept in anti-static bags when not in equipment.

If the trouble goes away with the swap, re-insert the original equipment to see if the problems return. Semi-conductors can get "hung up" in no-man's land, and simply reseating the card may restore service. If the swap has no effect **be sure you leave the original card in service**! The last thing you need is a suspect card in your spares.

A software "swap-out" is also possible. An example would be entering a known good IP address into a terminal. Make sure the real owner of the IP address is removed from the network however so duplicate address errors will not start up.

Always carry spare work area cords with you, as damaged cords are one of the most common components to fail in a network.

e) Look for critical components

Is the power plugged in? Is the equipment turned on? Is the work area cord securely inserted to the outlets at both ends? Was there a recent change in software or operating procedures? Has the equipment worked before, or was it recently installed and failed on turn-up? Work on the presumption that only one trouble exists, and think about which component could result in all the symptoms you have found?

Say you can not access the FTP server, but can access the Domain Name Server which is run on the same server. You know your trouble can not be the physical path, but most likely is an addressing or permission issue with the FTP Client/Server process.

Is everyone down on a coaxial bus? Look for a break on the bus, unterminated tees and segment ends. If everyone is down on a physical star, check the hub/switch and anything else which may be common to all users.

f) Reflect on your troubleshooting

Once you have found the trouble maker, mark it as bad order (if it is a piece of equipment) and either send it away for repair, or discard. Bad cords should be cut in half to ensure they do not find their way back into service.

Work the trouble backwards, now that you have the solution. Was there anything you could have done different to reduce the downtime? Did you spend time on a red herring, such as chasing the symptom and not looking at the trouble? For example, the symptom is "the network printer won't print." Did you chase down the printer application from the work station, only to find out no one on the network could print, and the cause was the A.C. plug had been removed by the janitor last night?

I: Network Specific Trouble Shooting

When a system is working it has to perform in a certain manner. When the system is broken, however, it may act in any possible way. Below are a few symptoms which are particular to the type of network in trouble, and some of the questions you could ask yourself during the troubleshooting process. This is not meant to be a comprehensive or a definitive list of possible faults and their causes, but is only intended to provide the student with an overview of some of the more common faults and their possible causes.

1: Telephone network

No dial tone:

Has it ever worked?
Can you hear a "pop" when hook switch flashed?
Yes? You have power to the telephone.
No? Check cables
Swap with known good phone.
Yes? Confirm original phone bad order
No? Check at main cross-connection for dial tone.
No dial tone at port of telephone switch
Switch maintenance contract? Call for service.
Your job? Reprogram switch or move to new port.
Dial tone at port of telephone switch?
Check physical channel back to phone, re-punch
cro ss connections.
Use a butt phone to determine where the dial tone gets lost.
Digital telephone?
Reverse the pair to check for polarity issues.

Wrong numbers going out.

Check with known good phone at work area, then at the switch port.
Most likely a programming issue in the switch.

Wrong numbers incoming

Call Forwarding from another local?
S witch programming

Unable to access specific trunks

Check telephone class of service.
Check access lists on trunks

Features missing

Feature turned off.
Check telephone class of service
Re-i nstall feature

2: Local Area Networks

Unable to access server

- Is it only one station, or many?
- If many stations, what is the relationship between the stations and the server? For example, are the members of a work group or sub-net unable to see the server?
- Is the user's account bad? Try your administrator account, or have someone try their client access account.
- Try a cold re-boot
- Check for hardware issues like IRQ conflicts, bad or missing drivers.
- Have any new programs been added lately? Some new programs may rewrite existing files, blocking access to them by the older programs.
- Can you access a neighbour using a peer to peer network operating system?
- Check the cabling, soft punches on cross connects, shaky patch cords.

Dropped Connections

- Is trouble limited to one station or many?
- Is the connection made through a router, a switch, or a bridge etc.?
- Is there a logical or physical connection which is being lost?
  - Check physical connections
  - Check for time-outs in the logical connection
- Try a cold re-boot to the station in trouble
- Check for hardware issues like IRQ conflicts, bad or missing drivers.
- Have any new programs been added lately?
- Eliminate memory issues by only loading software required to access the remote. Remove any TSR (terminate and stay resident) programs.

Slow Performance

- Check media performance by looking at the traffic analysis utility in the network operating system you are running. If the utilization rate is around 60% with a 5% collision rate, the network is likely saturated.
- Check the collision status counter. A collision rate over 5% is high.
- Expect to see more errors as traffic increases. As use goes to 100% collisions can also go to 100%. It is time to segment out or sub-network the network.
- Look for bursty collisions, where the collision rate increases, but the traffic rate does not change too much. If present, look for sources of EMI or RFI on the physical network (e.g. the photocopier near the LAN cables)
- Look for sources of reflection on the line; loose or bad connectors, pair untwist, crushed cables. If you have a TDR check the line for reflections.

Unable to see other members of work group

- Check station addresses and user name. Is the Work Group correct?
- Are some of the work group members present, but not others?
- Can the workstation locate any members through computer name search?
- Can you Ping any of the members?

General hints about LANs

- Try cold re-boot of the work station
- Check for hardware faults, IRQ conflicts etc.
- Check the physical network connections for bad cables, soft punches etc.
- Verify network adapter drivers are loaded correctly
- Check for changes to station, server or new applications
- If you have a LAN sniffer or protocol analyzer, learn it inside and out.
- Know what protocols you are running
- Keep your drivers updated
- Ensure the network is adequately protected from the outside by Firewalls and Virus checkers.
- Collisions on an Ethernet are not accidents, but a result of the Channel Access method used. Always expect a few percent collisions

3: Wide Area Network

General suggestions

- On delivery, or your appointment to the job of Network Administrator, observe any details you can.
- Record the appearance of the LEDS (e.g. is CTS on, what do the TX and RX LEDS do when traffic is on line?)
- Many WAN circuits will be Point to Point, using a Modem (an analogue to digital device), a line driver (digital to digital device), or some form of Multiplexing, which essentially is placing many separate communications channels on a single path. Locate, and copy, any material you can find on the equipment in use.
- Study the equipment while it is working, not in a faulted state, when the pressure from the users will only exacerbate the difficulties when troubleshooting.
- Be sure to record the "Who do I call" numbers, and the "What is the identifier" numbers for future troubles.

4: Coaxial Local Area Network

General Suggestions

- Although coaxial networks are no longer supported by the TIA/EIA standards, do not expect that you will never see one. Coaxial networks are larger troubleshot like UTP networks, with the exception that they are physical buses as well as logical buses.
- Check all connections for tees. If no work station is present, replace the tee with a barrel connector; do not install any terminators except at both ends of the coaxial bus.
- Remove all tap extensions. Some times a tee on the Thin-net bus will be extended by a length of coaxial cable to the location of a work station. Instead, run the tee with two barrel connectors and place the tee at the work station, as shown in Figure 10-xx below.

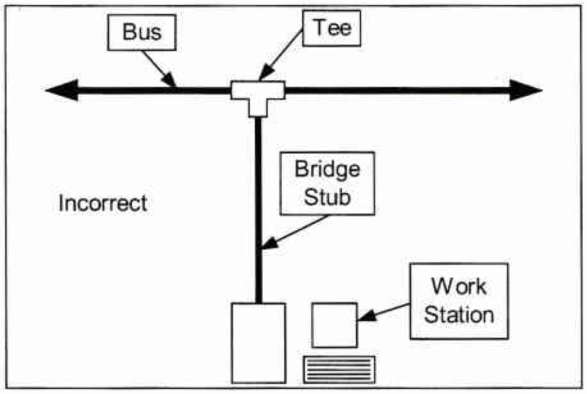

Figure 11-1 Incorrect Way of Adding a Drop on Thin-net

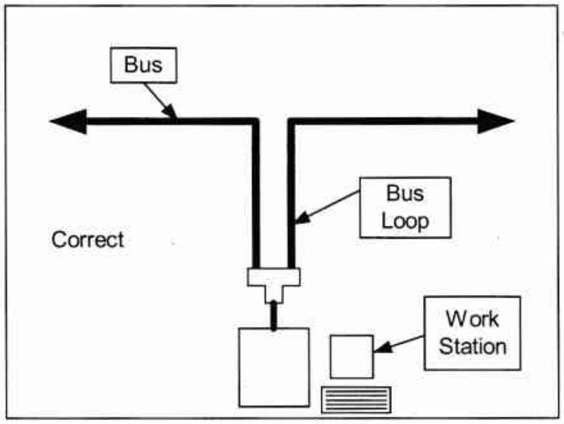

Figure 11-2 Correct Way of Adding a Drop on Thin-net

J: UTP Physical tests

1) Wire Map

The Wire Map test checks twisted pair cabling to verify correct pin to pin connections. In S.C.S. compliant systems, all 8 conductors in the horizontal cable must be connected, but many legacy networks required less. Visual inspection of the cabling and connectors will determine the current level of cabling, and the type of connections provided. Unless Category cabling is present, the specifications of the Standards documents for 100 ohm UTP cables are unlikely to be met.

Crossed pairs occur when two or more wires are reversed from end to end, thus resulting in a communication failure.

Split pairs occur when physical continuity is maintained but wires from logical pairs are split up. This error is more difficult to detect because there is still a pin-to-pin correspondence. POTS test equipment like a toner or an ohmmeter cannot find a split pair, but if the NEXT test result of your cable is less than 22 dB, then split pairs are likely.

Troubleshooting Recommendations

Wire mapping errors are most easily resolved by visual inspection at the connection points, but they have to be located first. The best medicine in this case is prevention. Ensure the colour code is correct when you are laying in the conductors, punching them down, and do one final check before moving to the next connector. Inspect and re-terminate as necessary.

If conductors are missing, it could be because they are unnecessary for the intended application, and the installation pre-dates the S.C.S. Standards. For example, 10BASET and token ring each require only four conductors. Some wiring designs purposely use one four pair cable to supply two RJ45 connections each with two pairs. This approach was often taken in legacy installations, with two of the pairs given to the phone lines, and two pairs used for a 10BaseT network. The important issue is to ensure the installed cabling meets the required design criteria.

If an open conductor is found, use the length measurement capability of your Scanner to determine whether the open is at the near or far end to speed fault isolation and Repair

The following faults are in non-complaint wiring schemes, which permit continuity on less than 8 conductors at a connector. If the cabling will support it, terminate all conductors present. Record the cable rating (Category or Level) and the number of conductors in your Network documentations.

Possible Fault: Crossed Pins: 1236 and 2136
Solution: Unless it is an unusual application requiring cross wires, rewire the connection. Re-configuration of the conductors should occur on the Work Area code, not on the horizontal cable. Again terminate all conductors present

Possible Fault: Expecting: 1236
Actual: 3645
Solution: 2-pair Token Ring cable is being used for a 10 BASE-T application. Change the cable or rewire connectors.

Possible Fault: Expecting: 3645
Actual: 1236

Solution: 10 BASE-T cable is being used for Token Ring application. Change cable or rewire connectors.

Possible Fault: Wires Missing
Solution: ISO and EIA standards require all 8 wires
10 BASE-T applications requires: 1236
Token Ring applications requires: 3645
ARC Net application requires: 45

Possible Fault: Open or Shorted conductors
Solution: Use Length to measure lengths of individual wires to pinpoint the location of the break. If the fault is at a connector and can be repaired do so. It the fault is between connectors, the cable should be replaced. **Do not** splice the cable to repair it.

2) DC Loop Resistance

Resistance is measured in a loop through each pair in the cable. For example, the value reported in ohms for pins 1, 2 is the resistance from pin 1 in the cable looped back to pin 2. During Auto test, resistance is said to fail if measured values on pairs used by the selected Network type is greater than the resistance for a maximum length loop (100 meters for most networks).

Troubleshooting Recommendations

In case of unexpected high DC resistance, compare the failed pair against other pairs in the cable. This will determine whether the issue is specific to the one failed pair or due to a problem affecting the entire cable. If a single pair is at fault, inspect termination points for a poorly made or oxidized connection. If a more sophisticated measurement tool is available with a TDR capability, use it to locate the distance to the fault.

If all four pairs have unexpected high DC resistance, check your assumptions. Did you allow for double the resistance to include the loop-back? Is the resistance assumption correct for the gauge of wire used? 26 gauge has higher resistance per foot than 24 gauge. Do you have an unusual patch cord in the link that could have high resistance? Look for anything unusual, especially if adjacent cables appear to be normal.

Possible Fault: Excess Length
Solution: Jacket length can be determined by recording the jacket length markings at both ends of the run. If possible re-route the cable by a shorter path. If the length is greatly in access of 90 meters (for a horizontal cable), use of a bridge or other active equipment maybe required.

Possible Fault: Poor Connection
Solution: Poor connections at punch blocks or T568A/B outlets can cause excessive resistance and thus signal loss. Inspect all termination points for good contact on connections. Inspect all contact surfaces of connectors and re-seat all connections.

Possible Fault: Incorrect conductor size. Conductors are measured in American Wire Gauge (AWG) size, with larger numbers being smaller sizes, and smaller conductors have larger DC resistance. Standard S.C.S. 100 ohm UTP is normally AWG 24 (AWG 22 is also permitted).
Solution: Verify that all the conductors are at least 24 AWG. Replace any cables with AWG 26, or larger AWG values, with 24 AWG Category cables. The cable

jacket has to be marked with the AWG value. If no markings present, replace it.

3) Propagation Delay

Propagation delay is the length of time it takes for a signal to travel from one end of a cable to the other, and is used by cable scanners to measure the electrical length of the cable. It is critical to ensure that the Nominal Velocity of Propagation is set correctly, which may require checking the manufacturer's published specification sheets. Typical NVP are in the range of 68% to 70% of the speed of light.

Troubleshooting Recommendations

Excessive propagation delay can have only two causes: either the cable is too long or the Nominal Velocity of Propagation was set incorrectly on the cable scanner. If you fail propagation delay, check to ensure that the pass/fail criteria match the design specifications. If so, the cable is too long. In many cases, a cable up to 25% too long (125m for Category 5e) will still support most LAN applications. However, the installation will fail most structured wiring standards, such as those published by the TIA and CSA.

In some cases, if the customer insists on the location of the terminal equipment, and an excessive length cannot be avoided, you can verify other cable parameters. If they pass, you can provide information that indicates the cable meets frequency-dependent parameters but is non-compliant with overall standards due to excessive length. This provides professional results to the user while placing on them the responsibility for non-compliant cabling.

Possible Fault: Excessive propagation delay

Solution: Propagation delay measurement is strictly a result of the Nominal velocity of Propagation value and the absolute time for the return trip. The only reasons for excessive delay are an incorrect NVP value or a cable that is too long. Check NVP, and if correct, try re-routing cable via a shorter path.

4) Propagation Delay Skew

Propagation delay skew is a measurement of the differential propagation delay within a 4 pair cable. It is an important measurement as some network implementations send 4 symbols at a time, one on each pair, to achieve high rates of transmission

Troubleshooting Recommendations

If the skew is high, provided the intended application is a 2-pair application such as 10Base-T or token ring, the application should still perform. If one pair is much higher or lower in delay than the others, very high skew may result. Examine the delay results for each pair. If one pair exhibits uncharacteristically high or low delay, re-examine the installation.

Possible Faults: Reported delay skew is excessive.
Solution: Pair lengths are too different. Check Pair 7&8 for short physical length, or pair 4 & 5 for over length

Possible Faults: Cable pairs have excessive length differentials.

Solution:	Splices and bridge taps on the cable run may cause a change in NVP resulting in an excessive skew. Replace the cable with Category 3 or 5e as required.

5) Length

Cable scanners use Time Domain Reflectometer (TDR) techniques to find the location of faults in cables. The length measurement is reported for each pair and compared to the length limit for the selected cable/network type. Length is reported in feet or meters.

The scanner uses TDR to determine length by sending a known pulse on a cable. When an impedance mismatch occurs, the pulse is reflected back to the source. Knowing the NVP of the cable and the time it takes for the reflected pulse to return the cable scanner can computer the length of the cable.

Troubleshooting Recommendations

One of the most common reasons for failing length on a test is the NVP is set incorrectly. If you are not careful and use the preset cable type it may not match the NVP of the cable under test. In this case, you can have an NVP difference of 10% or more, which translates directly into a length error. In the event the length is only slightly too long, check the NVP and cable type.

Assuming the NVP is correct, another cause of excess length is extra cabling looped in the ceiling or walls. Does the link in question meet the anticipated plan? Sometimes, for example in the case of an airline hanger or warehouse, a remote station may be forced to be over 100 meters from the wiring closet. If this has been planned for, and the intended application supports the excess length, then the link may fail structured wiring standards but still be approved for the application.

Some field testers allow customized auto tests to be configured that permit variances from standard TIA and ISO/CENELEC requirements. Such auto tests are useful in that they verify the installation meets requirements, allow for planned variances, and still the customer that "PASS" they're looking for.

Possible Fault:	Reported cable length is shorter than the actual cable length
Solution:	Punch blocks or other intermediate connections may cause a reflection before the end of the cable. If other test parameters are within limits, it may not cause a problem.
Possible Fault:	Length Exceeds Limits
Solution:	Check for excess cable coiled in walls or ceilings. This may not be a problem if Attenuation and NEXT readings are within specifications.
Possible Fault:	Length Measured Inaccurately
Solution:	Verify NVP in Scanner is set correctly for the cable under test. Also check for excess cabling in walls and allow for twists in twisted pair cables.
Possible Fault:	Can't Trace Cable to Find Location of Short or Open
Solution:	Use a toner to trace path from source to point

6) Attenuation

Attenuation is the loss in power of a transmitted signal as it travels along a cable. The longer the cable, the more loss there will be. Above a certain amount of loss, the cabling may not send network data reliably. Attenuation also increases with frequency; therefore 100 MHz will have higher attenuation than 50 MHz. on a Category 5e cable. Lastly, attenuation also increases with higher temperatures.

Troubleshooting Recommendations

The most common reason for excess attenuation is excessive length. Often troubleshooting for excessive attenuation will reveal excessive cable length.

Another possible reason for excessive attenuation is poorly terminated connections. A poor connection can add significant attenuation. Your clue to this cause is to compare the attenuation on the four pairs. If only one or two pairs have high attenuation, this suggests an installation issue. If all pairs have too much attenuation, check for excess length.

Temperature also affects attenuation in some cables. The dielectric materials, which form the conductor insulation and cable jacket, absorb some of the transmitted signal as it propagates along the wire. This is especially true of cables containing PVC. PVC material contains a chlorine atom which is electrically active and forms dipoles in the insulating materials. These dipoles oscillate in response to the electromagnetic fields surrounding the wires, and the more they vibrate, the more energy is lost from the signal. Temperature increases exacerbate the problem, because they make it easier for the dipoles to vibrate in the insulation. This results in increasing loss with temperature. This is why standards bodies tend to specify attenuation requirements adjusted for 20°C. Cables operating in temperature extremes can be subject to additional attenuation.

Possible Fault: Cable grade unsuitable for data rate
Solution: Replace cable, decrease data rate, or choose a different pair in the cable.

Possible Fault: Excessive length
Solution: Add repeater, check for excess wire coiled in ceiling or wiring closet. Is length within manufacturer's guidelines for your network type? Move user to a closer hub. If only slightly long, new higher grade cable may work.

Possible Fault: Non-twisted or poor quality patch cable (e.g., silver stain)
Solution: Replace with Category 5e patch cables.

Possible Fault: Poor punch-down block connections
Solution: Check and reconnect if necessary. 66 blocks will typically exhibit much more loss than 110 or Krone blocks, and should not be used in S.C.S. structures.

Possible Fault: Poor T568A/B connections or other terminations
Solution: Verify that conductors are seated properly. Check for tight wire twists at all termination points.

7) <u>Capacitance</u>

A cable scanner is required to test this parameter as normal capacitance measurement devices are not sensitive enough to measure the low values present. For twisted pair cable, Capacitance is measured between conductors in a pair. For coaxial cable, the Capacitance is measured between the conductor and the shield.

Troubleshooting Recommendations

The fist thing to look for is a distortion of the cable jacket. Too tight a cable tie, (cable unable to slide through the tie), or use of non-depth stopped staple will cause an excessive capacitances. Too low a capacitance is normally the result of excessive untwisting of the UTP.

Possible Fault: Lower than Expected Capacitance
Solution: Check for a broken conductor in the cable, split wire pairs in the near end connector, the wrong type of cable or excessive noise on the cable.

Possible Fault: Higher than Expected Capacitance
Solution: Check for shorted conductors or shield, the wrong type of cable (lower grade); an open cable termination; or excessive noise on the cable.

Possible Fault: Erratic Capacitance
Solution: Check for intermittent cable connections or excessive noise on the cable.

Possible Fault: Lower than Expected Capacitance
Solution: Check for a broken conductor in the cable, split wire pairs in the near end connector, the wrong type of cable or excessive noise on the cable.

Possible Fault: Higher than Expected Capacitance
Solution: Check for shorted conductors or shield, the wrong type of cable (lower grade); an open cable termination; or excessive noise on the cable.

Possible Fault: Erratic Capacitance
Solution: Check for intermittent cable connections or excessive noise on the cable.

8) <u>Insertion Loss Deviation</u>

Insertion loss is a kind of attenuation caused by variations in the characteristic impedance along a pair of conductors. These variations may be caused by changes in the cables physical structure, such as jacket distortion due to over-tight staples, or to excessive untwisting of the pair at a connector.

Troubleshooting Recommendations

Insertion losses are caused by variations in the impedance of the cable structure, or by the losses associated with a splitter or divider in the line. The most efficient way of transmitting energy from one end of the cable to another is to have matched cable impedances at the input to the cable, in the cable itself, and at the output of the cable. The characteristic impedance of a 100 ohm UTP cable is determined by the distributed Inductance of the cable (per meter) and the distributed capacitance of the cable (per meter),

***Possible fault*:**	Excessive insertion losses in a Fiber Optic link
Solution:	Clean connectors and re-measure. Check for excessive bends in cable

***Possible fault*:**	Excessive losses in a metallic link
Solution:	Check for bridge taps or splitters on line. Look for some cause of excessive losses, e.g. a splice on the cable, sub-standard cables (i.e. POTS cabling)

9) NEXT Near End Crosstalk

NEXT is a measurement of the effect the signal on one pair has on another pair in the same cable. Its' name comes from the telephone world where you could literally hear someone else talking on the channel between you and your called party. Their signal would "bleed over" from their metallic pair to yours. Category cabling reduces the effect of all forms of cross-talk by maintaining a tight twist in the pairs in a cable.

Troubleshooting Recommendations

In many cases, excessive crosstalk is due to poorly twisted terminations at connection points. All connections should be twisted to within 13 mm of the point of termination. The first thing to do in the event of a NEXT failure is to use the field tester to determine at which end the NEXT failure occurred. Once this is known, check the connections at that end, and replace or re-terminate as appropriate.

If this does not appear to be the problem, check for the presence of lower Category patch cords (such as voice grade cable in a Class D installation). Another possible cause of NEXT failure is split pairs, discussed earlier. This should be identified automatically with the wire map function of your field tester. Female couplers are another high source of crosstalk and should not be used in a data installation. If a cable is not long enough, replace it with a cable of the required length rather than adding another cable.

Sometimes a NEXT failure is caused by an inappropriate test has being selected. For example, you cannot expect a Category 3 installation to meet Category 5e performance requirements.

In event you have eliminated all of the above NEXT sources are still experiencing NEXT failures, contact the system designer for further assistance.

Possible Fault:	Use of couplers
Solution:	Elimination of couplers will reduce NEXT. The fewer the total number of connections in the link, the lower will be your total NEXT.

Possible Fault:	Grade of cable
Solution:	Verify that the grade of cable is suited to the application.

Possible Fault:	Multiple applications
Solution:	Use of additional pairs to carry data for other applications can affect NEXT. Ensure wiring is used for hub-workstation communication only. Other traffic should be re-routed to different cables.

Possible Fault:	Substandard components
Solution:	The overall quality of the link will be determined by the quality of its weakest component. For Category 5e links, all components: cables, patch cords, terminations, connectors, patch panels and punch blocks must be rated Category 5e.

Possible Fault: Test adapters/patch cables
Solution: Where test adapters or patch cables are necessary, use high grade adapters or high grade cables with the minimum possible length. Use of non-twisted pair patch cables, i.e., silver satin will adversely affect NEXT.

Possible Fault: Pair twists
Solution: Examine cable for loose or untwisted cabling, particularly up to blocks, T568A/B connectors, and/or wall plates. Category 5e connections require a maximum of 13 mm (0.5 inch) untwisted wires at any termination.

Possible Fault: Split pairs
Solution: Ensure logical pairs are twisted together.

10) Power Sum NEXT (PSNEXT)

Since PSNEXT is a calculation based on NEXT measurements, troubleshooting for PSNEXT failures reduces to troubleshooting for NEXT problems. Once you have isolated and repaired the NEXT problem, PSNEXT will automatically improve.

Troubleshooting Recommendations

Possible Fault: Excessive PSNEXT value
Possible Solution: Determine the pair with the excessive PSNEXT. It is likely that on of the combinations used for the NEXT values was close to the limit due to excessive untwist or removal of the jacket. Check for untwist and jacket removal at the connector closest to the fault.

11) Attenuation to Crosstalk Ratio (ACR)

ACR is derived from NEXT and attenuation data. Any steps taken to improve either NEXT or attenuation performance will improve ACR performance. In practice, this usually means troubleshooting for NEXT, because the only way to significantly improve attenuation is to shorten the length of the cable. Both Attenuation and NEXT are measured and the ACR value is computed at each measured Attenuation frequency.

For successful sending and receiving on cables, the received signal must be stronger than the noise. In unshielded twisted pair (UTP) networks, attenuation determines the strength of the received signal, while the noise is primarily the NEXT from the station's own transmitter.

The net result is that the exact strength of the NEXT or the absolute amount of attenuation is not as important as the difference between two. This is the Attenuation to Crosstalk Ratio (ACR).

ACR assumes the hub resends the signal. The only attenuation suffered is the loss between the hub and the workstation. Most new hubs are of this type.

Troubleshooting Recommendations

Generally, a cable length increases, attenuation increases and ACR gets worse. An additional factor is frequency. As signal frequency increases, ACR also decreases. NEXT and attenuation both worsen with increases in frequency. This means that margins measured on a particular network type will be different for the same physical cabling when used for network types that operate at different frequencies. For any given cable, he higher the frequency, the worse the ACR will be.

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Possible Fault: Connections Poor
Solution: RJ-45 or punch block connections can lead to excessive resistance and attenuation. Verify that conductors are seated completely and that the correct type of connector/wire combination (stranded or solid) is used.

Possible Fault: Grade of Cable
Solution: Verify that the grade of cable is suited to the application. Replace cable, decrease data rate, or possibly use a different pair in the cable.

Possible Fault: Length of Cable
Solution: Excessive length can cause signal loss. Add a repeater or check for excess cable coiled in ceilings or wiring closets. Check that length is within manufacturer's guidelines for the network application.

Possible Fault: Patch Cables
Solution: Where patch cables are necessary, use high grade cables with the minimum length possible. Use a non-twisted pair patch cables can adversely affect results.

12) Power Sum Attenuation to Crosstalk Ratio (PSACR)

Since PSACR is a calculation based on ACR measurements, troubleshooting for PSACR failures reduces to troubleshooting for ACR problems. As mentioned earlier, troubleshooting for ACR reduces in turn to troubleshooting NEXT and attenuation. Once you have isolated and repaired the ACR problem, PSACR will automatically improve.

13) Far End Crosstalk (FEXT)

Far End Cross Talk issues are troubleshot the same as NEXT, always keeping in mind that the FEXT trouble is seen at the far end of the cable from the disturbing end.

Troubleshooting Recommendations

The same factors that contribute to NEXT problems contribute to FEXT problems. So troubleshooting for ELFEXT reduces to troubleshooting for FXT and attenuation problems, just as you would for ACR problems. Look for sources of cross talk like un-twisted pairs, or a source of high attenuation such as extra cable coiled up in the ceilings.

14) Equal Level Far End Crosstalk (ELFEXT)

ELFEXT is similar to ACR, except it uses FEXT instead of NEXT, and is therefore a better measurement to use when dealing with high speed, parallel transmission like 100-BaseT4 or Giga-speed systems.

Troubleshooting Recommendations

The same factors that contribute to NEXT problems contribute to FEXT problems. So troubleshooting for ELFEXT reduces to troubleshooting for NEXT and attenuation problems, just as you would for ACR problems.

15) Power Sum Equal Level Crosstalk (PSELFEXT)

PSELFEXT is a result of ELFEXT across multiple pairs. A PSELFEXT failure would be result of an out of parameter ELFEXT value, or higher than permitted attenuation of a pair.

Troubleshooting Recommendations

Higher than expected FEXT on one pair, or higher than expected attenuation may skew the PSELFEXT values on the cable. Look for a marginal pass on FEXT, or on Attenuation, and find away to reduce to either of the values which are margin. Attenuation can be reduced by reducing overall length, while FEXT may be reduced by reterminating the outlets and cross connections. Watch for excessive untwist in the pairs or too much jacket being removed.

16) Return Loss

Troubleshooting Recommendations

There are many possible causes for return loss failures. These include variable patch cord impedance, patch cord impedance changes due to handling effects, installation practices, and lack of link margin in TIA model, non-compliant cable, and non-compliant connecting hardware. The TIA is working to specify patch cord return loss requirements, as well as improve the link model. The current model allows worse-case compliant components to fail the link limits, which is clearly unacceptable.

Installation practices are more important on Category 5e and 6 than they were for Category 5. Additional unnecessary untwist in terminations can add several dB of return loss in some cases. Be sure to apply a high level of care when installing cabling that requires return loss qualification.

TDR techniques may be able to indicate gross impedance changes, but are generally insufficient for pinpointing the source of a Category 5e or 6 return loss failure.

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TDR techniques may be able to indicate gross impedance changes, but are generally insufficient for pinpointing the source of a Category 5e or 6 return loss failure.

17) Characteristic Impedance

Characteristic impedance of the cable pairs will effect the reflection of the pair, and its ability to pass the full energy value onward to the receiver. Because of the nature or Characteristic impedance, any mismatches at connectors or transition points can cause a variation in the impedance value, reducing the forward transmission of energy and causing ref\lections on the line.

At this point in time, Characteristic Impedance is not a measured value required for testing, with the cable manufacturers' taking the responsibility of maintaining a characteristic impedance of 100 ohm plus or minus 15%.

18) Alien Crosstalk

Alien crosstalk may become a large problem when running high speed networks on multi-pair backbone cables. The possibility of cross talk from another 4 pair cable sub-assembly with the 25 pair becomes a definite issue. At this time, there are no cable scanners, with economical access, that will test the cross-talk of 25 pairs. As a result, even the standards (TIA/EIA-568.B2) only require that 25-pair be treated like 4-pair, in that crosstalk and the power sum values are based upon dividing the 25 pair into 6 four pair cables, with the 25th pair required to meet the 4-pair limits with any other 3 pairs in the cable. d

K: The Network Administrators Tool Box

The Network Administrator requires only a limited number of hand tools, plus their own troubleshooting abilities, in order to provide an efficient, timely resolution of network issues. Remember that no matter what level of equipment is provided by your employer, what he is really buying is your ability to discern symptoms from the problem, in effect buying your ability to ensure that network downtime is reduced to a minimum. Your ability to resolve network faults will ultimately prove your worth to the company.

1) The Hand Tools

Punch tools for the connection you have on site (Type 66, BIX, 110, or Krone)
Screwdriver set (Robertson green and red handle, 1/8 and 3/16 flat, 2
sizes of Philips screwdrivers)
6 inch Diagonal cutters
6 inch needle nose
Cable jacket ringers (4-pair and 25 pair)
8 inch pliers
S cissors
Tool pouch
Coaxial cable crimping tools
Silver satin crimping tools
Drywall saw
Portable drill with various bits
2 or 4 foot bell hangers bit

2) Basic Test Equipment

Toner and chaser set
110 VAC tester and chaser
Butt Phone
6 and 8 position banjo break-outs
Volt/ohm meter
Cabl e Quick tester
Banjo adapters (outlet break out box)

3) Cabling Tools

Glow-rods or similar extenders
100 foot Fish tapes
Pull cord

4) Software Tools

Bootable diskette (MS-DOS or similar)
Restore diskette for Network operating system
Full range of Utilities provided with the network operating system
Log files running constantly in the background.
Client applications which will increase the user's ability to understand and
Analyze any problems on the network. The following is a partial list of the
software available in various versions of Windows:

Upp er layer protocols

File Transfer Protocol Client (FTP.exe) to work into FTP Server. Provides access to the files on a distant computer.

Simple Network Management Protocol agent (SNMP.exe) to work a SNMP manager

TELNET client (Telnet.exe) Provides access to the applications of a distant computer as if you were at the distant
comp uters keyboard.

TCP/IP Protocol Suite

ARP.exe Detects invalid ARP entries in the Address
Re solution Protocol tables on the local computers.

Nbtstat.exe Check the connections on NetBIOS over
TCP/IP, updates LMHOSTS cache, determines
regi stered name and scope ID.

Net.exe

Netstat.exe Display the statistics and state of a current
TCP/IP connection

Ping.exe Check host names and IP address, and TCP/IP
config uration. Use Ping 127.0.0.1 (Loop-back number) to test the work stations TCP/IP stack

Route.exe Adds deletes or changes the network routing tables.

Tracert.exe Checking the route to a specific IP address

Winipcfg.exe Provides information on DNS and DHCP
serve rs, NIC and modem physical addresses etc.

Memory mangers

Debug.exe Debug utility tests and debugs executable files.

Defragmentation (Defrag.exe) Reorganizes files on a disk to optimize performance. Places all pieces of a file in consecutive order onto the hard drive. Speeds up read processes

Scandisk.exe Checks disks and file systems for damage and repairs the files if needed.

Operating System Utilities

Tuneup.exe Windows 200o utility similar to Sysedit in Win 95

Msconfig.exe Utility brings up System.ini, Win.ini, Bootf.ini, Services and Start-up files for review and
editing.

Sysedit.exe Utility brings up all major DOS supporting files,
inclu ding Autoexec.bat, Network.ini, etc

Network Utilities

Hostname.exe Returns the hostname of the PC you are
laun ching this command on.

Sysmon.exe A dynamic tool used to monitor various aspects of system usage such as Threads usage, CPU
1usage, File usage, and Client/Server usage

Administrative Utilities

Net Watcher This applet monitors remote computers which are accessing the files on your computer.

Network Monitor Agent (nmagent.exe)

Monitor applications

Log files which run in the background and record activity and errors on a specific device or piece of software. Typical devices which may have logging available include the modem, and protocol stacks. Always check your hardware and software Devices to see if logging is available, and launch logging if possible.

Appendices

A Glossary

Alarm Jack Also known as a dialler outlet. An eight position, non-keyed RJ-31X type assembly with shorting bars across terminals 1–4 and 5–8.

Analogue The description of the continuous wave or signal such as the human voice for which conventional telephone lines are designed. Signal comprised of many different and constantly changing voltage. Compare with Digital signals.

Analogue Loop Back A test device used to loop back an analogue signal from the transmitter to the receiver at the same end. The return signal may then be used to check for signal impairments such as attenuation, noise and frequency roll-offs.

American Wire Gauge AWG refers to the size of the single physical conductor in a cable, with larger AWG values representing small physical sizes. Most telecommunication conductors are 24 AWG, but larger 22 AWG and smaller 26 AWG are also used. House 110Vac conductors range from AWG 10 to AWG 14.

Asynchronous Transfer Mode ATM is a high bandwidth, low delay packet and multiplexing system using small fixed length cells with header and information fields.

Asynchronous Transmission A data transmission that is synchronized by a transmission start bit at the beginning of a character and one or more stop bits at the end.

ATM See Asynchronous Transfer Mode

Attenuation Attenuation is a loss of signal strength between the transmitter and the receiver. Losses generally increase with longer distances and higher frequencies. High attenuation rates will increase the Bit Error Rate of a channel

AWG See American Wire gauge

Backbone cable A physical connection between the main distribution frame (cross-connect) and the intermediate or horizontal distribution frames (cross-connection). Abbreviated BC

Balanced Interface Each signal uses two physical wires, one a signal lead and the other a common return lead. The use of two wires per signal allows higher data rates over greater distances as compared to unbalanced interfaces. V.35 and RS-422 are examples of balanced interfaces.

Balun An impedance matching transformer used to convert the impedance of one interface to the impedance of another interface. Generally, baluns are used to connect balanced twisted pair cabling with unbalanced coaxial cabling. Abbreviation of the terms “Balanced/Unbalanced”.

Bandwidth The bandwidth of a channel is a measurement of either; 1) the band of frequencies an analogue path can carry without unacceptable losses or 2) the maximum bit rate which a digital channel can carry without unacceptable BER

Basic Link Term for the Horizontal cable, T/O and Horizontal termination (i.e. the Permanent Link), with an extra two 2-meter test cords that are used to connect the cable scanner to either end of the Permanent Link.

BC See Backbone Cable

BER See Bit Error Rate

BERT See Bit Error Rate Tester

Bit Error Rate Tester A device used to test the bit error rate of a communication circuit.

Bit Error Rate The ratio of the number of bits incorrectly received to the total number of bits transmitted.

Bridge Definition 1: To connect one circuit or component to another in parallel. Definition 2: The interconnection or equipment used between two networks using the same communication protocols, transmission method and addressing structure.

Bus A common pathway for communications. A bus is a single physical pathway that all stations use to communicate, on a time-share basis.

Canadian Standards Association The CSA is a government/industry body that is mandated to provide industry-wide standards for Canadian companies which are based upon international standards.

Carrier Sense, Multiple Access/Collision Detection CSMA/CD access to the communication channel used by Ethernet (IEEE 802.3) networks.

Central Office The phone company switching facility or center, which is usually a Class 5 office where subscribers' local loops terminate.

Centrex A "PBX" located in the telephone company's C.O. which provides services similar to a private switch, to a customer. Centrex was common where a company has a number of branch offices in a municipal area.

Channel A telecommunications pathway between the transmitting terminal and the receiving terminal. A Channel is generally considered to be the path between the transmitting user and the receiving user.

Characteristic Impedance The impedance value of a transmission line with uniform physical parameters (e.g. conductor size, conductor separation etc.) does not vary with length or frequency, but is a fixed characteristic of the line. UTP cables, for example, have a Z_0 of 100 ohms.

CO See Central Office

Coaxial Cable A coaxial cable has an insulated inner conductor surrounded by an outer cylindrical conductor. Examples of coaxial cables include Cable TV and radio transmitters. Coaxial cables are run as unbalanced transmission lines.

Compliance A device or system which meets all the characteristics defined in some standard. A TIA/EIA 568-B compliant cable system, for example, has to meet all the mandatory issues defined in the TIA/EIA 568-B document.

Conductor Any substance which can conduct (i.e. carry) an electrical current.

Connecting Block See Cross-connection

Critical Angle The angle that a ray of light has to hit a refractive boundary in order for the ray to be reflected by the boundary. Rays of light hitting the boundary at an angle larger then the critical angle will undergo Total Internal Reflection

Cross-Connect In metallic cable structures, a cord or cable which is used to join two or more terminated conductors together. In fiber optic systems, a device such as a barrel connector panel used to connect the optical fibers together. Also may refer to the hardware used to terminate the conductors.

Crosstalk A form of electrical interference where a valid signal from one pair of conductors induces a noise signal on a second pair of conductors. Crosstalk is a major source of errors on Local Area Networks.

CSA See Canadian Standards Association

CSMA/CD See Carrier Sense, Multiple Access/ Collision Detection

Daisy Chain A method of wiring multiple jacks in parallel across a single pair. This method is not used in TIA/EIA 568-B networks, but may be found in older telephone cable structures and in 10-Base-2 or 10-Base-5 networks.

DARPA See Defence Advanced Research Projects Agency

Data Communication Equipment The equipment that provides the functions required to establish, maintain and end a connection. The equipment also provides the signal conversion required for communication between the DTE and the telephone line.

Data Terminal Equipment Data Terminal Equipment. A device which transmits data to and, or receives data from a serial data communications system, i.e., a computer or terminal.

dB See Decibel

DCE See Data Communication Equipment

Decibel A dB is a ratio of two values, often the input and output signal strengths. Decibels come in a number of variations including the dBm, which measures the strength of a signal compared to 1 mWatt.

Dedicated Inward Dialling DID trunks are only used for inward calling, from the PSTN to the subscriber. An internal user (i.e. a local) can not dial out on these lines.

Defence Advanced Research Projects Agency DARPA is an agency of the American Department of Defence which was instrumental in creating the Internet by developing TCP/Protocols using Request for Comments.

Demarcation A point at which two services may interface and identify the division of responsibility, such as the point of interconnection between telephone company facilities and the users' terminal equipment.

Demark **See Demarcation**

Digital A transmission mode where data is represented by discrete signal elements. Digital traffic may have binary (on/off) states or multi-level digital signals using 2 to some whole value power (e.g. $2^3 = 8$ levels).

Digital Loopback A device used to loop back a digital signal from the transmitter to the receiver at the same end. Digital loopbacks are used to check the BER on the path.

Distribution Frame A cross-connection point which may be a Main Distribution Frame (MDF), an Intermediate frame (IDF) or Horizontal frame (HDF) where cross-connections may take place.

DTE See Data Terminal Equipment

DTMF See Dual Tone Multi-Frequency

Dual Tone, Multi-Frequency A DTMF signal is used by most telephones as a method of sending dial signals. Each digit (0 to 9) has a unique set of two tones to represent that digit. Earlier phones (i.e. rotary phones) used dial pulses to send addressing information

E&M Trunk signalling method used generally used between a switching system and a trunk in telephones networks. The abbreviation comes from the terms Earth & Magneto or Ear and Mouth.

EF See Entrance Facility

EMI See Electro-magnetic interference

ER See Equipment Room

Electro-magnetic Interference Electrical "noise" caused when a conductor radiates electromagnetic (radio) waves. These waves can cause a noise to be inducted in an unrelated conductor. Common sources of EMI include photo-copiers, fluorescent lights, and electric motors.

Entrance Facility The area where outside cables enter a building. This area is distinguished by the (usual) presence of lightning protection, demarcation blocks and the building ground. The entrance facility is a defined space under TIA/EIA 568-B.

Equipment Room A defined space under TIA/EIA 568-B. The ER contains major telecommunications equipment, such as the PBX (the telephone switch) or a server farm. The ER may also contain Horizontal terminations, the Entrance Facilities, and the Telecommunications Main Grounding Busbar.

Ethernet A protocol used on local area internets. The standardized Ethernet protocol is referred to as the IEEE 802.3 standard, while the earlier (and non-standardized) version is generally referred to as Ethernet 2.

Far End Cross Talk A crosstalk measurement process where the amount of crosstalk present is measured on a disturbed pair at the far end from where the signal is being transmitted. Compare to Near End Crosstalk.

FDDI See Fiber Distributed Data Interface

FEXT See Far End Crosstalk

Fiber Distributed Data Interface A dual counter rotating ring topology based on fiber optics operating at 100 Mbps. Has a standardized fiber optic interface.

Foreign Exchange. A service that provides a connection between a premise and a central office other than the one that services the Exchange area in which the premise is located. An example is providing a Vancouver dial tone to a Toronto client. The client could access the FX trunk to provide toll-free calls to the Vancouver area.

Four-Wire Circuit A circuit using 2 pairs of conductors, one pair for the send path and the other pair for the receive path, hence the 4-wire term. The 2 paths provide a full-duplex operation.

FT-1 Flame Test Rating 1. Cables with this rating can be used in combustible buildings, e.g., wooden houses. Cables with FT-1 ratings are rarely found in commercial buildings.

FT-4 Flame Test Rating 4. Cables whose jacket while not promote combustion, that is, the jacket requires a higher temperature to burn then the jacket can produce. This cable is to be used in non-combustible buildings, i.e., concrete apartments. FT-4 is also known as riser cable, and is normally the minimum fire rating used in most commercial structures.

FT-6 Flame Test Rating 6. Wire with this rating to be used in plenum installations. Cables with this rating have the same characteristics as FT-4, but in addition do not produce toxic fumes. FT-6 cables are for use in Plenum (breathable air) spaces.

Full Duplex Channels capable of carry transmit and receive signal simultaneously. Networks using full duplex operation are capable of transmitting data at more than twice the simplex rate.

FX See Foreign Exchange

Gain A gain is an increase in signal strength, usually due to additional amplification. Gain is the opposite of Attenuation.

Gateway 1) A device used to provide an interconnection between two networks with different communication protocols.
2) Commonly used to denote an on-ramp to the internet (i.e. a gateway router)

Glare The simultaneous seizure of opposite ends of a trunk circuit.

Ground Start Signalling supervision method commonly used from the PABX to the switching center. It is designed to prevent a condition called glare, which is two users, one incoming and one outgoing, seizing the same line at the same time. A ground is put on one lead to indicate seizure of the line.

Half Duplex A communication channel which can only transmit a signal in one direction at a time. An example is a 2-way VHF radio system which allows both users to talk to each other, but only one may transmit at a time.

HDF See Horizontal Distribution Frame

Headroom Headroom describes the "distance," in decibels, between a particular measurement and the permitted value at that point. A positive headroom value indicates he measured value is acceptable, whereas a negative headroom value is a failed test.

Home Run A home run cable is a cable which connects two telecommunications spaces directly, with no splices, bridge taps or daisy chains. Home run cables are TIA/EIA 568-B compliant.

Horizontal Cable The physical cable which connects the work area outlet with the horizontal termination point. So called because the majority of these cables are "horizontal," starting and ending on the same floor (i.e. horizontally placed).

Horizontal Distribution Frame A termination block used to terminate horizontal cables in a Telecommunications Room, which provides a cross-connection point to either active equipment at that location, or to the backbone cable.

Hub A Hub is generally any central device which joins a physical Star network such as an Ethernet hub or Layer 2 Switch.

IDF See Intermediate Distribution Frame

IEEE See Institute of Electrical and Electronics Engineers.

Impedance Impedance is the resistance a conductor presents to alternating current signals. Direct current resistance forms a component of impedance, along with distributed inductive and capacitive reactances on the transmission line. Impedance is a vector value, measured in ohms, at some angle.

Institute of Electrical and Electronics Engineers The IEEE is an industry body which provides standards for various electronic and telecommunications systems, including the IEEE 802-x series of LAN standards.

Integrated Services Digital Network A switched digital network, providing two data rates of 144 kbps (Basic Rate Interface) and 1.544 Mbps (Primary Rate Interface). Commonly used in telephony as lines and trunks, ISDN can provide voice, video and data services.

Intermediate Distribution Frame An IDF is the termination point for second level backbones in the TIA/EIA 568-B standard.

International Standards Organization The ISO is an organization of the United Nations which is involved in establishing and promoting international standards of many types. The main ISO standards in telecommunications are the ISO 11801 and the establishment of the 7-Layer OSI Model

Internet Protocol A protocol created by DARPA by the RFC process. Established the 32 bit IP address and other associated parameters. A Layer 3 protocol which is used on the Internet, and may also be used on LANs.

IP See Internet Protocol

ISDN See Integrated Services Digital Network

ISO See International Standards Organization

Jack See Telecommunications outlet

Jackfield A panel of jacks (i.e. T568-A outlets) where links may be cross-connected to produce a channel. Jackfields may include monitor positions as well as termination positions.

Jumper A 2, 3 or 4 pair set of conductors used to connect termination positions on punch block type. Jumpers are normally twisted 1 pair conductors.

Key System Key systems are private switching equipment used by small business to provide multi-line appearances and intercom services from individual telephones. Key systems do not provide trunk pools or many other features of a PBX.

LAN See Local Area Network

Link A telecommunications pathway which represents a "hop" in the channel, with many links producing the Channel. Examples include radio links used to receive an AM broadcast radio signal. The turns channel starts at the microphone, CD, live broadcast and is transmitted using Amplitude Modulation radio processes. Your car tuner combines the Receiver (to AM demodulator), an amplifier, completing the channel to your speakers, and then to your ears. The path from the disk jockey's voice and your ears is the channel, with many links along the way

Local Area Network A LAN is a physical network which supports a small physical area, such as a room, a floor, or a building. LANs join together network devices such as PCs, printers and wireless transceivers. Compare to Wide Area Networks.

Local Loop The physical conductors connecting the telephone subscriber equipment (i.e. the phone) to the line terminating equipment in the central office, usually a metallic circuit either 2-wire or 4-wire.

Logical Topology The operational shape of the network, which is determined by the network protocol in use. The logical topology does not have to be the same as the physical topology.

Loop Start A method of signalling toward the local Telco switch to indicate that a telephone has gone "off hook" and dial tone is required. It is the most common method of signalling between a single line phone and the local CO. When "off hook," the local loop closes and causes line current to flow signalling the CO to provide dial-tone.

Main Distribution Frame The MDF is the termination hardware which is connected to a major piece of equipment, such as a PBX switch. The service is distributed throughout the building from the MDF via the backbone cables to the IDF, cross-connected to the HDF and ultimately ends up at the work area device.

Mbps See Mega-bits per second

MAN See Municipal Area Network

MDF See Main Distribution Frame

Mega-bits Per Second A Mbps signal is a digital signal which is capable of transmitting 1 million bits per second on a channel. Compare to mega-Hertz.

Mega-Hertz A MHz signal is an analogue signal which is capable of transmitting 1 million signals per second on a channel. Depending on the number of signals the system supports, the bit rate may be equal to, twice, four or more times the bit rate in Mbps. Compare to Mbps.

MHz See Mega-Hertz

Modular 1) Composed of modules which may be "plugged" together
2) The plug end of a cord designed to mate with an outlet, i.e. a modular jack.

Municipal Area Network A physical network which covers an area greater than a LAN, but less than a WAN. Examples of MANs include SONET rings and ATM networks.

Mode An operational "path" which light rays may follow. A single-mode optical fiber will only support one pathway, and all light must follow the same path. A multi-mode optical fiber permits many different pathways in the same fiber, and a light pulse will be dispersed (i.e. stretched) in this fiber, which will reduce the total amount of signals,that M/M fibers can carry. Single-mode fibers have a much higher bandwidth than multi-mode fibers.

Modem A device that transforms signals from digital to analog and vice versa. The term comes from an abbreviation of the terms Modulate and Demodulate.

Monitor 1) A device that displays text or graphic information, such as a video display terminal, or 2) A non-invasive test point where a signal may be tested.

Multi-mode A multi-mode optical fiber has a core large enough to support multiple paths for light to travel down. Multi-mode fibers have smaller bandwidths than Single-mode.

Multi-port A multi-ported communications device serving several stations via an individual port for each station.

Multiplexer A device that merges data signals from multiple channel devices for transmission over a single composite line. May be a Time Division MUX (TDM), a Frequency Division MUX (FDM), Wavelength-Division MUX (FDM) or Space-Division MUX (SDM)

MUX See Multiplexer

Near-End Cross Talk A measurement of cross-talk caused by a transmitter on one pair, with the cross-talk measure at the same end as the transmitter, but on another pair

Network A combination of active and passive equipment which will support telecommunications of various types and speeds. A grouping of systems with inter-work with each other and may be responsive to outside demands (e.g. bandwidth on demand or self-healing structures)

NEXT See near End Cross Talk

Null Modem A device which allows the connection of two DTE devices by emulating the physical connections of a DCE device. Sometimes known as a "Roll Cable."

Off Hook A telephone or modem is being used. Indicates a busy condition to incoming calls.

On Hook A telephone or modem is not being used. The on hook condition opens the DC loop, indicating that calls can be accepted.

Open Office Use of movable partitions to create a work space which can be easily reconfigured as usage requires. A common office technique used in many businesses

Open System Interconnect A networking model which divides the function of networking into 7 Layers. These layers permit a non-vendor and non-application specific structure to support easy communications.

OSI See Open System Interconnect

Outlet See Telecommunications Outlet

Patch Cord

PBX See Private Branch Exchange.

Peer-To-Peer Network A network in which all devices have equal status and abilities for file transfer, printer sharing, etc.

Performance Compare with Compliant. Performance parameters are only part of a compliant structure.

Permanent Link The portion of the horizontal cable, including the T/O and horizontal termination point which is permanently built into the building structure

Physical Topology The physical shape a network takes on. Compare with Logical topology.

Plain Old Telephone Service The older telephone systems, which had no real standards

Plug See Telecommunication Outlet

Plenum A plenum is a space containing breathable air. Part of the HVAC system in a building.

Point-To-Point A single communications circuit connecting just two locations.

Polarity Having a defined polar direction, such as the electric field direction in a wave, or the tip before the ring in a termination

Poll and Select An access method used mainly in Tree topologies

Private Branch Exchange. Telephone switching equipment dedicated to one customer. A PBX connects private telephones to each other and to the public dial network.

Protocol An agreed upon set of rules which permits two devices on a network to communicate with each other

POTS See Plain Old Telephone Service

Power Sum A process of using linear addition to determine the combined effect of multiple disturbing pairs.

Premises The client, user or subscriber's place of business

Protocol The rules for timing, format, error control and flow control during data transmission. An agreed upon set of rules for communicating between two devices.

Protocol Stack A selection of protocols from a Protocol Suite, with one protocol only from each Layer present in any one message

Protocol Suite A unified, inter-working set of protocols designed to promote ease of communication between two terminals. A Protocol Suite may include more than one protocol at any OSI level, and many of the protocols may have only a limited use.

PSTN See Public Switched Telephone Network

Public Switched Telephone Network The domestic telecommunications network commonly accessed by ordinary telephones, key systems and PBX trunks.

Reflection The process whereby light or other EM waves bounce off a surface such as a mirror.

Refraction The process whereby light or other EM waves will bend when entering a 2nd material. Compare with reflection.

Registered Jack An outlet used for telephone and data systems which has a specified number of internal connections and a specified wiring configuration. RJ-11 and RJ-25 are common 2 and 3 pair telephone outlets

Remote Loop Back A test that sends a signal to the remote modem to test the local modem, the remote modem, and the circuit between them.

Return Loss A signal which has been reflected back to the source due to an impedance anomaly, or an open or short on the transmission line. Causes a loss in the forward moving signal, and may result in echoes if severe enough

Request for Comments A method of creating an open architecture network by publishing ideas and suggests of improvements on a public network. RFCs are the main process by which DARPA developed the Internet.

RFC See Request for Comments

Ring 1) Ring voltage on a phone
2) See Tip and Ring

Riser A riser cable is normally a backbone cable which is vertically hung between floors of a multi-level building. Riser meaning the act of "rising" the signal from one floor to the next. Riser rated cables are designed to restrict the passage of flames up the cable. FT-4 cables

RS-232 The EIA standard that defines the electrical characteristics and pin definitions for the 25 pin DB-25 connector. Commonly used to connect DTEs and DCEs. The RS-232 standard is equivalent to CCITT V.24 and V.28.

RJ See Registered Jack

Screened Twisted Pair 100- Ohm cable which has a foil or shield to increase EMI immunity.

S.C.S. See Structured Cable System

ScTP Screened Twisted Pair

Simplex Simplex communications is communication in one direction only. Many two-way communications paths are actually composed of two simplex paths, one for communication in each direction.

Single-Mode An optical fiber which has a small core size which only permits light to travel in one path.

Silver Satin Flat, untwisted cable typically used as a telephone extension cord. Silver satin cords should never be used in a LAN network because they do not meet the high standards of NEXTA etc.

Shielded Twisted Pair Cable composed of pairs of insulated wire twisted around each other and surrounded by shielding material usually made of foil and/or braid. As well, the entire group of wires may have a common shield or each pair may be shielded individually.

Short A low resistance path between two conductors, which often will bypass the desired loading device. A short circuit

Splice A physical joining of two conductors or optical fibers which is usually considered permanent.

SONET See Synchronous Optical Network

Standard A recognized and documented process which has been standardized to achieve certain defined and evaluation performance levels

Star Wiring Star wiring provides a dedicated cable from each work area outlet to a centralized location in a telecommunications room. Also known as Home run wiring.

STP See Shielded Twisted Pair

Structured Cable System A cable infrastructure built to be compliant to national and International standards, such as the TIA/EIA 568B document.

Subscriber A customer of a telephone company or other data or voice carrier company.

Synchronous Optical Network A MAN network using fiber optic OC-x equipment in a physical ring topology. Commonly found as an autonomous (i.e. independent) network

Synchronous Transmission A transmission in which the data characters and bits are transmitted at a clock rate between the transmitter and receiver, providing greater efficiency by eliminating the need for individual start and stop bits for each byte.

T1 A digital transmission link with 1.544 Mbps bandwidth. T1 operates on two twisted pairs and can handle 24 uncompressed voice conversations, each digitized at 64 Kbps.

TCP See Transmission Control Protocol

Telco An abbreviation for any telephone company providing basic POTS service to business and residential customers. May also be known as a Common Carrier.

TIA/EIA See Telecommunications Industry Association/Electronics Industry Association

Telecommunications Industry Association/Electronics Industry Association

An industry body formed under the American National Standards Institute to develop electronic and telecommunications standards. Similar to the Canadian Standards Association in Canada.

Telecommunication Outlet A jack provided with 8 connectors to provide an interconnection for all 4 pairs in a horizontal cable. TO may be wired using either the T-568A or T-568-B configurations. Other outlets, such as 2 or 3 pair telephone jacks, are referred to as USOC or RJ outlets.

Termination Termination is the process of ending a link or a channel onto some form of mechanical connector, which provides for a method of cross-connecting cables or equipment.

T&R. See Tip and Ring

Tip and Ring The two conductors associated with a 2-wire cable pair. The term tip and ring derived their names from the physical characteristics of an operator's cord switchboards. Examples of T&R interfaces include: USOC-2, T568A and T568B. Generally, but not always, used as a balanced transmission line.

Thick-net Thick-net is another name for an Ethernet 10 BASE-5 system, which uses a large (i.e. thick) coaxial cable as its bus.

Thin Ethernet Also called Cheap-net. Normally describes the Ethernet 10 BASE-2 system which uses a coaxial cable substantially smaller than Thick-net.

Token Ring An earlier form of LAN, which provides lower speed, but better security, than Ethernet. Originally on STP cables as balanced transmission lines, now normally placed on TIA/EIA568B install, with Baluns and other non-compliant WA cords used to interface

Token Passing Token passing is a channel access method using a token which is passed in a pre-determined order amongst the members of the network. Similar to the First Nations use of the Talking-Stick to control communications

Topology The topology of a network may be either the physical shape that the network cable takes (i.e. the Physical Topology), or the operational shape the network devices take (i.e. the Logical Topology).

Total Internal Reflection Using materials which have different velocities of propagation in order to confine light to an area of the optical fiber (i.e. the core)

Transmission Control Protocol A Layer 4 protocol used in the TCP/IP Suite to provide connected "error-free" service.

Transmitter A transmitter is a device which transmits signals onto a channel. The signal may be either analogue or digital, and may be transmitted as electrical pulses, radio signals or light pulses.

Tree Topology A network with one workstation at the top position, and all other workstations "branched" off from the trunk. Networks using Tree topology include IBM 3270 systems and generally use Poll and Select access methods

Twisted Pair A pair of metallic conductors twisted together to reduce cross-talk and to provide consistent impedance to AC signals.

UDP See User Datagram Protocol

Unbalanced Interface All the interchange circuits of the interface share a common signal ground. The RS-232 and RS-423 are examples of unbalanced interfaces. Compare with Balanced Interface

Universal Service Ordering Codes A numbering scheme used to identify the number of connections and type of module end used in telephone work, originally a Bell System term. A 4p4c (4-pair4-conductor)

User Datagram Protocol A Layer 4 protocol construction in TCP/IP Suite, with less overhead than TCP, but subject to "best effort" or connectionless transmission.

Unshielded Twisted Pair Generally 4-pair cables, with each pairs having a precision twist length, inside an insulating sheath. UTP within the TIA/EIA-568 B document has an impedance of 100 ohms.

USOC See Universal Service Ordering Code

UTP See Unshielded Twisted Pair

V.35 An international standard (CCITT) termed "Data Transmission at 48 Kbps using 60–108 KHz Group Band Circuits." It is, however, used for much higher speeds. It is typically used for DTEs or DCEs that interface to a high speed digital carrier.

WA See Work Area

WAN See Wide Area Network

Wide Area Network A WAN may range from city-sized to global. Because of its size, protocols which are effective in LANs can not be used in WANs, and some topologies, such as Mesh or Point to Point become more common, while rings and buses are not used at all

Work Area 100 square meters or a 10 X 10 foot office space. Open offices may use short "pony walls (e.g. Dilbert's cubicle). The WA usually contains a desk, a phone data set, and may contain fax, dedicated data (permanent or switched) services, etc.

Work Area Cord Braided 26 or 24 AWG 4 pair cable in TIA/EIA 568-B, used to connect work area station to T/O in Work Area. May also be special-built (e.g. DB-9 or 8 conductors, USOC 2, 3 or 4 outlets. Common component failures as cords are subject to abuse and damage

Work Station A terminal device such as a telephone, printer or computer which a user may use to interface with a network.

B T/O configurations

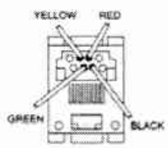
Standard 4-Pair Wiring Color Codes

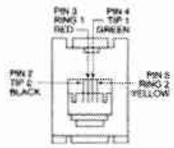
PAIR 1	T	White/Blue
	R	Blue/White
PAIR 2	T	White/Orange
	R	Orange/White
PAIR 3	T	White/Green
	R	Green/White
PAIR 4	T	White/Brown
	R	Brown/White

Note: For 6-wire jacks use pair 1, 2 and 3 color codes.
For 4-wire jacks use pair 1 and 2 color codes.

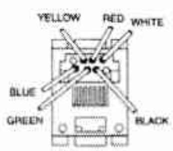
Pin #	Jack Type		
	8P8C/8P8C Keyed	6P6C	MMJ
1	Blue (L)	White (W)	Orange (O)
2	Orange (O)	Black (B)	Green (G)
3	Black (B)	Red (R)	Red (R)
4	Red (R)	Green (G)	Yellow (Y)
5	Green (G)	Yellow (Y)	Black (B)
6	Yellow (Y)	Blue (L)	Brown (N)
7	Brown (N)	—	—
8	White (W)	—	—

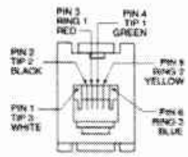
6P4C

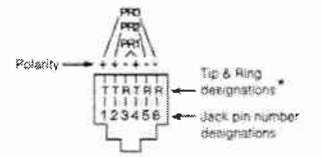




6P6C



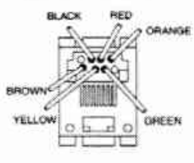


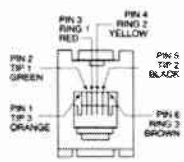


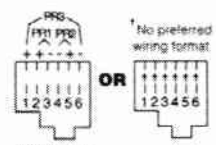
USOC

*Some equipment standards may vary from the standards shown here.

MMJ

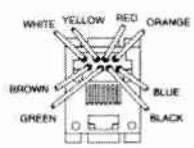


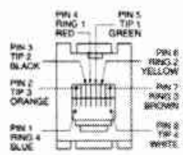


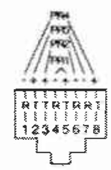


DEC Pairing

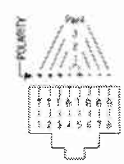
8P8C and 8P8C KEYED, USOC





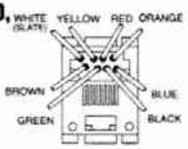


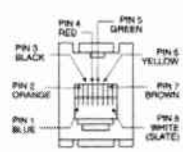
GENERIC USOC

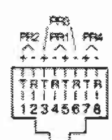


RJ61X APPLICATION

8P8C and 8P8C KEYED, T568A, T568B (WECO), 10Base-T

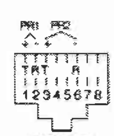






T568B/WECO / AT&T 258A

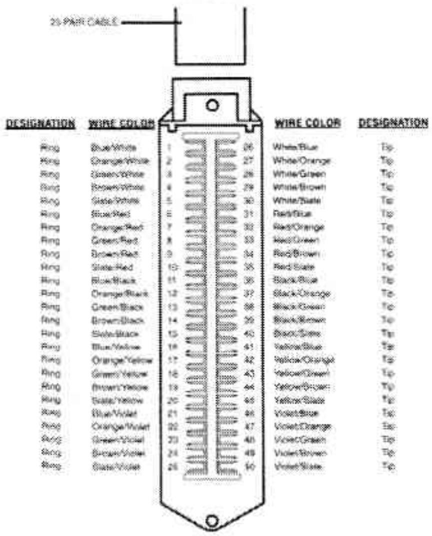
T568A

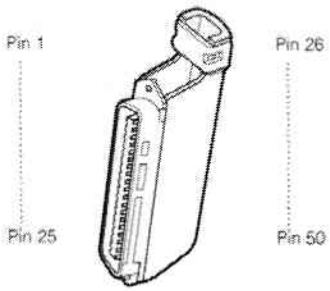


10BASE-T (4-wire Ethernet)

25-PAIR COLOR CODING/ISDN CONTACT ASSIGNMENTS

RJ21X





Electrical Network Connection

From one to twenty-five single or multiple-pair circuits bridged to the network or other connected equipment.

Mechanical Arrangement

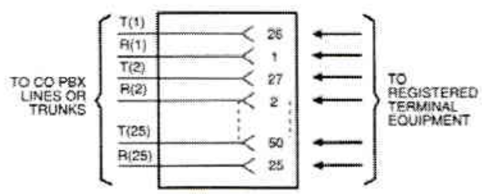
Circuits are provided on numbered tip and ring positions on a miniature 50-pin ribbon connector ("Amphenol-type"). Pins 1 (ring) and 26 (tip) are considered position 1. Pins 2 (ring) and 27 (tip) of the ribbon connector are position 2. This pairing continues through twenty-five pairs.

Typical Usage

Many key and PBX systems specify the RJ21X as the network interface device. Many of these systems also use the RJ21X, or "Amphenol-type" as a connector for stations or telephone sets, wired from the KSU or PBX Main Distribution Frame.

Note: Sometimes an RJ11 or RJ14C jack can be installed in place of an RJ21X jack. If the system requires only a few lines but the RJ21X is specified on the registration label, under FCC Part 68 you may specify an RJ11C, RJ14C, RJ25C or RJ61X instead.

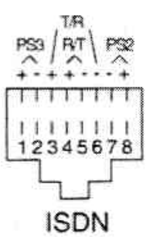
Many Leviton jacks can be used for the RJ21X configuration where "intermixing" is permitted. Substitution of these special jacks is often both economical and practical. Contact Leviton Telcom Applications Engineering for information about versions to meet your requirements.



ISDN Assignment of Contact Numbers as specified by ISO Document 8877: 1987 (E)

Contact assignments for plugs and jacks:

Contact Number	TE	NT	Polarity
1	Power source 3	Power sink 3	+
2	Power source 3	Power sink 3	-
3	Transmit	Receive	+
4	Receive	Transmit	+
5	Receive	Transmit	-
6	Transmit	Receive	-
7	Power sink 2	Power source 2	-
8	Power sink 2	Power source 2	+



Note: For use in TE to TE interconnections, power source/sink 3 shall conform to the requirements specified in CCITT Recommendation I.430, section 9.2 for power source/sink 2.

This appendix contains descriptions of Universal Service Order Codes (USOC) for connecting telephone instruments and related equipment to telephone lines, based on Part 68, Subpart F, Section 68.502 of FCC regulations, and as described by the T1E1.3 Working Group on Connectors and Wiring Arrangements.

A NOTE ABOUT USOC CODES

USOC Codes, developed years ago by the Bell operating companies to identify service or equipment under tariff. Information on USOC codes is provided here should you run across these in your work.

APPLICATION CROSS REFERENCE

Application:	USOC Number:
Single-line telephone instruments	RJ11
Single-line accessories	RJ11
Connecting modems to telephone lines	RJ11
Answering machines	RJ11
Two-line telephone instruments or accessories	RJ14
Connecting three lines to a single telephone set	RJ25C
Multiple-line answer/announce systems	RJ25C
Burglar and fire alarm circuits	RJ31X, RJ38X
Fixed loss loop	RJ45
Programmed data equipment	RJ45
Up to four access lines	RJ61X
1.544 Mbps digital services or other data services	RJ48

NOTE: RJ21X can be found on page C-2.

A Note About USOC Number Suffixes

RJ (Registered Jack) numbers end with a letter that indicates the wiring or mounting method:
"C" identifies a surface or flush-mounted jack.
"W" identifies a wall-mounted jack.
"X" identifies a complex multi-line or series type jack.

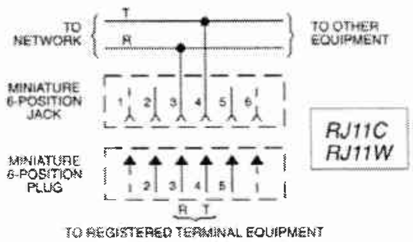
RJ11C/RJ11W

Important: Refer to "note on USOC codes" page 2-8.

Electrical Network Connection: Single-line connection with bridged tip and ring

Mechanical Arrangement: Miniature surface-mount six-position jack (RJ11C), or miniature wall-mount six-position jack (RJ11W)

Typical Usage: Connects single line to a telephone instrument or other device (such as a modem or answering machine) in a residence or small business. RJ11 connectors are often specified for small key and PBX systems, wiring one line to one device to simplify installation, troubleshooting, and repair. Connects single-line telephones to individual extensions of a PBX that requires only tip and ring.



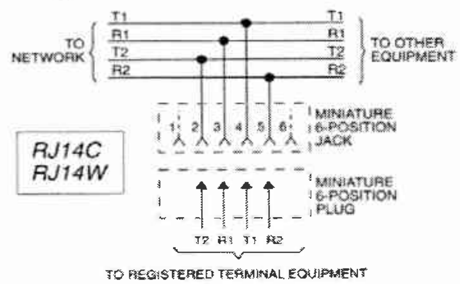
Note: In both RJ11C and RJ11W connectors, only two terminals are wired. Green (tip) connects to position 4 and Red (ring) to position 3 of the connector. The connection is bridged (parallel) like a duplex on a branch circuit. There are no other connections to any other pins on the connector.

RJ14C/RJ14W

Electrical Network Connection: Two-line bridged tip and ring.

Mechanical Arrangement: Miniature surface-mount six-position jack (RJ14C) or miniature wall-mount six-position jack (RJ14W)

Typical Usage: Connects two lines to a single telephone set or other device. Often used in small key system and two-line residence applications. Note: Two lines are bridged (connected in parallel) on positions 3 and 4 (line 1) and on positions 2 and 5 (line 2).

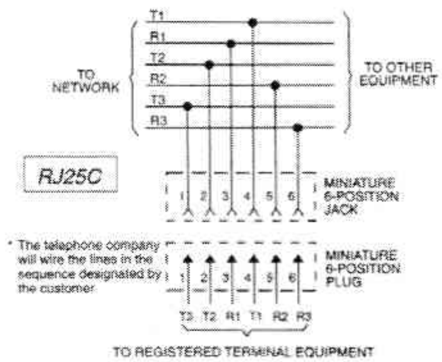


RJ25C

Electrical Network Connection:
Three tip and ring circuits (lines). Connection to a single six-position device in bridged configurations.

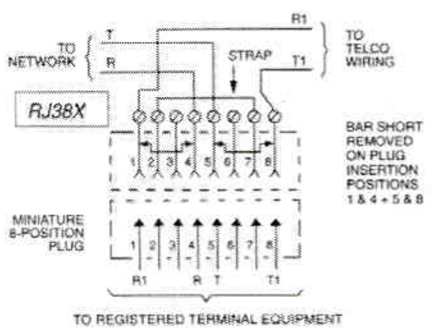
Mechanical Arrangement: Miniature flush-mount six-position bridged three-line jack.

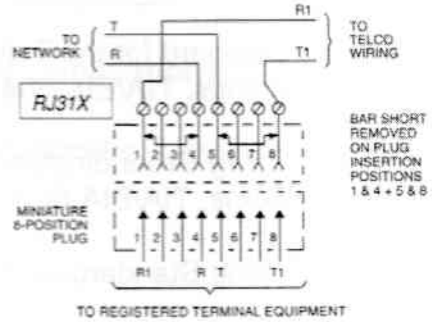
Typical Usage:
Connects three lines to a single telephone set or other device. Three lines are bridged (connected in parallel). This configuration is normally used for special applications such as message registration, multiple-line answer/announce systems, and similar services.



RJ31X, RJ38X

The FCC has deleted these codes from Part 68. Although not a current USOC number, they continue to appear in common use, especially in security applications.

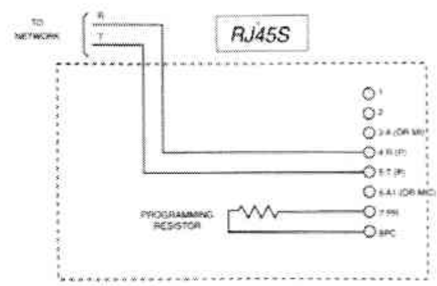




RJ45S

Important: Refer to "note on USOC codes" page 2-8.

Electrical Network Connection Single line bridged tip and ring with programming resistor.
Mechanical Arrangement Miniature eight-position keyed jack.
Typical Usage Connects computers and other data equipment to the telephone network.



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Model 77A and 77M Tone Test Set

Harris Corporation TS21 Craft Test Set

D: Sources of Illustrations

BCIT has permission from the following publications:

Wiring Strategies for Voice and Data Networks, Leviton Telecomm, 1998
1-800-722-2082, info@levitontelcom.com

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Figure

Model 77A and 77M Tone Test Set

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*Harris Corporation **TS21 Craft Test Set***

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